SCIENTIFIC AGRICULTURE

Vol. XVII MARCH, 1937 No. 7

THE PRODUCTION OF FLUID MILK IN THE EDMONTON AND CALGARY MILK SHEDS[1]

G. H. CRAIG[2], J. PROSKIE[3], AND V. A. WOOD[3]

[Received for publication February 15, 1937]

PURPOSE AND SCOPE OF STUDY

An examination of the existing combination of land, labour, capital and management on dairy farms in the Edmonton and Calgary areas with a view to determining the combination contributing most to profitable operations is the purpose of this study. By way of introduction, a review of the physical features and population of the two regions is presented.

Success in operating a farm is dependent upon the proper combination of the means of production. The fitting or adjustment of the land resources, power, equipment, live stock and labour to the organizational abilities of the farmer (management) and to the price with which his products will receive, is the problem of the agriculturist. This fitting or adjusting of the factors of production has become more and more immediately related to changing world needs with the increasing inter-dependence of our economic society.

The 67 farmers included in this survey sold milk to large distributing agencies or direct to city customers. Receipts from the sale of this product constituted the major source of income; farm organization was, therefore, focused upon the production and sale of milk. Additional revenue was obtained from the sale of cream, butter, eggs, vegetables and the like.

PHYSICAL AND SOCIAL PATTERN OF THE COMMUNITIES

The part played by physical factors of soil, climate and transportation is vital to any clear conception of the production system. So also are the population elements and the institutional framework important as moving factors in the situation. Each will be evaluated in turn. But the chief interest, however, is the combination of the factors of production in their relation to price and cost. The first in the natural sequence of factors are those of physical and climatic nature and the social organization of the community.

Regional Physical Factors

Edmonton and Calgary are the two large urban centres in the Province of Alberta. The population of each is approximately 80,000 persons. To

[1] This study was conducted by the Department of Political Economy, University of Alberta. It was made possible by a grant from the Carnegie Trust Fund, additional assistance being supplied by the Economics Branch of the Dominion Department of Agriculture, Ottawa.

The field work was completed during the summer of 1934. Farm records formed the basis for analysis. These records were obtained by personal interview with the farm operator.

Much credit for the statistical analysis is due E. N. Davidson.

[2] Formerly Lecturer, Department of Political Economy, University of Alberta.

[3] Student Assistants.

supply perishable agricultural products to these cities, the adjacent rural areas have developed certain restricted lines of production. They supply fluid-milk, cream, butter, eggs, vegetables and other produce. These were the main enterprises on the farms close to the cities.

The soil and topographical features of the two areas differed considerably. In spite of this, the same general commodities were produced in each of the rural areas due to the similarity of city demand. The Edmonton district is the Alberta centre of the black, highly productive Park Soil. It is a soil well adapted to the production of a variety of foodstuffs required for local urban consumption. In Calgary, on the other hand, the soil is of the Brown Prairie type and better adapted to extensive farming than to the production of perishable farm products. One index of this can be expressed in the value of land per acre in Edmonton and Calgary. The value per acre of land among the forty Edmonton dairy farms included in the study was $58.00 as compared with $33.00 per acre in the Calgary district. Further evidence of this fact comes from the extent of the milk shed in each area. Edmonton drew its fluid-milk supply from within a fifteen mile radius. Calgary, on the other hand, drew from as far as fifty miles, although the large proportion of its supply came from within a twenty mile radius. This is one indication of lesser productivity of the Calgary soil.

While soil is a very important item, it must be considered along with certain other physical factors. Precipitation in average years is sufficient in each of the districts to give productive results from the cereal grains and from most of the vegetables generally grown in northern latitudes. In Edmonton, the 49-year average rainfall up to 1932 was 17.27 inches.[4] In Calgary the 48-year average up to that date was 16.60 inches.[4] While the average rainfall was almost identical in the two areas, there were some differences in evaporation which favoured production in the Edmonton district. Another factor of some importance was that of annual variation in precipitation. At Edmonton, there was less variation than at Calgary, and the latter climate can be, agriculturally, much better or much worse than the Edmonton climate.

The matter of variability of climate is one that plays a rather important role in the production of farm products. Annual milk production figures for the Calgary area showed wide variations. Calgary distributing companies had much difficulty in some years in supplying the total demand for milk at the prevailing prices. However it must be mentioned here that climatic factors are not the only ones involved in the variability of milk production. The business cycle is also important. The prolonged depression contributed greatly to the continued surplus of milk for the "city-sweet trade" during past years. This will be discussed in a later section of the report.

Another vital factor limiting the agriculture of an area is frost. The average frost-free period for twelve years in Calgary was ninety-four days as compared with only eighty-seven in Edmonton. This gave Calgary farmers an advantage in growing wheat. The greater chance of early frosts in the Edmonton district meant more specialization in growing feed crops, which in turn encouraged the livestock and dairy industry as markets for the feed.

[4] 1933 Canada Year Book—pages 52, 53.

The natural vegetation in both Calgary and Edmonton was such that pasturing on unbroken tracts was quite common. The higher nutritive value of the Calgary native grass offset partially the annual precipitation fluctuations which caused short pastures in that area. Edmonton pasture lands very seldom had such dry years that grass would not grow in abundance. However, due to the proximity to the centres and consequent high land values, farmers often were forced to increase the productivity of the pastures by seeding them down to tame grass and hay. The extent of this will be dealt with in a later part of the report.

The topography of the two areas plays its natural part in the distribution of the farms and transportation systems. The Saskatchewan river runs through the Edmonton territory from southwest to northeast. In Calgary the Bow and the Elbow Rivers run from west to east. These rivers are the chief topographical barriers in the two areas, but neither has been very influential in changing the time-distance from farm to city. The transportation routes were not greatly lengthened at any point because of their presence. Otherwise the two areas are fairly level with only minor coulees breaking the contour. The valley between the Bow and the Elbow west of Calgary, does probably define, in combination with soil factors, the most fertile section in the Calgary milk shed. This valley is known as Springbank, and is the section in which the largest group of fluid-milk producers were found.

In all sections of the two areas, trunk lines of gravel highways developed, close to which the milk producers were to be found. With the exception of a few farmers who were outside the twenty mile radius from the city-centre in Calgary, the fluid-milk was transported daily by truck to the milk distributors. This truck service developed with the growth of gravelled highways. It contributed much to the lessened use of the railway in the delivery of farm products within a relatively short distance of the centres.

This, then, is a general picture of the influence of physical factors in the Edmonton and Calgary rural-urban areas. The part played by soil, precipitation, frost, topography and transportation has been introduced. These will be carried through the study as they relate to various phases of production. The population elements found on the land is the next focus of attention.

The People and Their Social Organization

The Calgary and Edmonton districts are relatively mature agricultural areas and the farm population is characterized by normal age and sex distributions. The average age of the operators was 48 years, which compares with that of the typical agricultural area that has passed through the frontier stage. Originally the settlers were mostly young men and only a small number were women. However, with the development of farming, the establishment of community services, transportation and marketing facilities, the numbers of men, women and children became normal and with them a normal pattern of social and business organization. The same applies to the ethnic and racial origins of the people. In the beginning the French and half-breeds were the chief settlers. Later, the development of specialized agriculture and stable markets encouraged

settlement by those with training in the lines of production required by those markets. Seventy-eight per cent of the farmers interviewed were of British origin and the remainder chiefly of German and Danish descent. These people were accustomed to dairying and market gardening, and naturally displaced those whose habits did not fit them for the type of farming required in the area.

The city is the centre for most of the activities of the farmers in these areas. The products of the farm are hauled directly to the urban centre and here the commodities of consumption are purchased. The cash basis upon which city trade is conducted has influenced the organization of the farm very greatly. The dairy farmer is by no means a self-sufficing unit but rather a specialist who sells his products for cash and buys from urban stores the needs of his farm and family.

The limited area from which milk is drawn and the mutual city centre are the basis for close contact between the farmers. As a consequence, a relatively strong milk producers' organization developed in each district which was very influential in the development of government regulation in the marketing of milk. In both cities the Public Utilities Commission of the Provincial Government has been given power to regulate the production and the price of the commodity.

THE ECONOMIC FACTORS OF PRODUCTION IN THEIR FARM MANAGEMENT RELATIONSHIPS

The detailed analysis of the farm records forms the main body of this section. Point will be given to various cost, price and profit relationships. These will be in answer to the question:— What are the factors which influence the combination of enterprises and the selection of enterprisers in the farm business? All this is in terms of the combination of the four factors of production:— Land, Capital, Labour, and Management. A summary will first be presented of such factors as size of farm, utilization of land, and values of farm property which apply to the factors of Land and Capital.

Land and Capital

Size of Land Unit per Farm

There still remain in the Edmonton and Calgary districts a few of the original settlers. These men began their operations in the district on quarter-section homesteads in most cases. First settlement was largely completed before the turn of the present century. Since that time the size of farm has been adjusted to the type of production which the operators pursued. The farms of dairy producers interviewed varied from about one acre, nearby or within the city limits, to one thousand acres some distance from the centre. On the farms around Calgary and Edmonton there were found a number of operators who kept their stock on very small acreage and bought all their feed. Others followed the principle of producing most of the fodder consumed by the stock. The size of the farm depended largely upon choice of fodder supply. Where very large farms were found, it happened frequently that the operator carried on supplementary or complementary enterprises in combination with milk production.

Table 1.—Classification of farms according to acreage

Acres	All milk farms	Edmonton	Calgary
1 - 10	4	—	4
11 - 50	6	2	4
51 - 160	22	17	5
161 - 320	19	13	6
321 - 480	9	6	3
481 - 640	3	—	3
Over 640	4	2	2
All farms	67	40	27

Table 1 shows the distribution of farms according to size. The Calgary farms are more evenly distributed from the very small to the very large. In the Edmonton district, on the other hand, the large proportion of farms are in the quarter- to half-section classification, with only a few either lower or higher. It is a peculiar fact that many dairy farmers in the Calgary district find it more convenient or more profitable to use no more land than is required for farm buildings. Frequent occurrence of dry seasons make the production of feed too irregular. It is claimed by some at least, to be more advantageous to purchase all feed than to grow it, especially since heavy capital and labour charges are required on a large tract of land in order to produce sufficient feed for the dairy herd. The small unit of land leaves the operator more time to spend on the specialized function of producing milk. Near Edmonton a quarter- or half-section farm will produce sufficient roughage and pasture for relatively large herds without the use of very great proportions of labour and capital. In the Calgary district larger land units are required to maintain the same level of feed production.

It is a question of some importance as to whether farms which contain only one acre of land should be included in a study of this kind. These were considered in the report for one major reason:— A current problem among the dairy farmers is the relative profitableness of complete specialization in the production of milk, to the exclusion of fodder production, as compared with partial diversification to include the production of milk and also of fodder, sometimes in combination with such other enterprises as grain growing or hog feeding. It is to point out the differences in operating methods and in success that the very small farms have been used in the study.

It is significant that the producer-distributors were found in greater numbers among those on the "postage stamp" farm.[5] Six of the nine producer-distributors in Calgary were on farms of less than 50 acres. The largest farm operated by a producer-distributor was 241 acres, most of which was pasture. It would appear that the production and distribution of retail milk is a sufficient number of enterprises for one operator without the added responsibility of producing feed as well. The size of the land unit is definitely related to the degree of specialization carried out and also to the productivity of the land.

Utilization of Land

The great differences between farm operators in their use of the land has been indicated by the variations of occupied area. This section on

[5] No producer-distributors are included in the Edmonton farms.

land utilization is a further indext to point out the same tendency and to define the use made of land on various sizes of farms.

The relative profitableness or unprofitableness of varying sizes of farms will be dealt with in due course. At this point it is only necessary to present the acreages and other crude indexes of comparison between the uses of land. Table 2 presents the average and percentage distribution of improved and unimproved acreages in Edmonton and Calgary districts.

TABLE 2.—AVERAGE AND PERCENTAGE DISTRIBUTIONS OF OCCUPIED ACREAGE

Number of farms	Edmonton		Calgary				All farms	
	Milk shippers		Milk shippers		Producer distributors			
	40		18		9		27	
	Acreage	Per cent	Acreage	Per cent	Acreage	Per cent	Acreage	Per cent
Total cropland	176.7	65	199.1	54	11.0	19	136.3	51
Improved pasture	13.8	5	12.7	3	—	—	8.5	3
Farmstead	5.5	2	6.3	2	1.4	3	4.7	2
Total improved land	196.0	72	218.1	59	12.4	22	149.5	56
Wild pasture	53.3	20	141.4	38	44.6	78	109.2	41
Woodland	18.8	7	—	—	—	—	—	—
Wasteland	2.1	1	11.5	3	—	—	7.5	3
Total unimproved land	74.2	28	152.9	41	44.6	78	116.7	44
Total acreage	270.2	100	371.0	100	57.0	100	266.2	100

For all 40 farms in the Edmonton district, 72% of the occupied area was improved in one way or another. In the Calgary district, the parallel figure was only 56% for the 27 farms in the study. The remainder of the land was chiefly in pasture.

Among the nine producer-distributors in Calgary, whose acreages were very small and who were nearest the city, 78% of the land was in wild pasture. The 18 milk shippers in Calgary, on much larger farms and slightly farther from the city, had 38% of their land in wild pasture and an added 3% in improved pasture. In Edmonton, the 40 farmers, including no producer-distributors, had 20% of their land in wild pasture and 5% in improved pasture. The higher yielding soil of the northern park belt carries a much larger number of cattle per acre on its pasture.

In the southern district, 51% of the occupied acreage was used for cropping, and in the Edmonton district, 65%. The Edmonton farmers produced a much larger proportion of their own feed, especially of the bulky roughage.

From Table 3 it can be seen that much the largest proportion of land is used for producing feed-threshed and for bundles and hay. This is especially true of the Calgary producer-distributors who had 88% of their land in bulk feed crops. Among the milk shippers, who are found somewhat further out from city centre, some of the land is devoted to cash crop

wheat, but the larger proportion is used for the production of threshed grain feed and roughage. It might be mentioned here that the threshed grain for feed is largely oats, and the roughage is largely greenfeed. From the records it was discovered that the largest farms grew the highest proportion of wheat. The smaller farms closer to the city, with few exceptions grew very little wheat and depended on their cropland to provide bulky feeds.

TABLE 3.—AVERAGE AND PERCENTAGE DISTRIBUTIONS OF CROP ACREAGE

Number of farms	Edmonton		Calgary				All farms	
	Milk shippers		Milk shippers		Producer distributors			
	40		18		9		27	
	Acreage	Per cent	Acreage	Per cent	Acreage	Per cent	Acreage	Per cent
Wheat	38.4	22	23.0	12	—	—	15.3	11
Threshed grain feed*	62.1	35	66.1	33	—	—	44.3	32
Other feeds†	42.5	24	69.6	35	9.7	88	49.5	36
Hoe crops	1.5	1	0.7	—	1.3	12	0.9	1
Summerfallow	30.7	17	36.2	18	—	—	24.1	18
Breaking	1.5	1	3.5	2	—	—	2.3	2
Total cropland	176.7	100	199.1	100	11.0	100	136.4	100

* Oats and barley.

† Corn, sweet clover, sunflower, alfalfa, green feed, hay.

The proportion of feed which a farm operator plans to produce is the chief criterion of land use. The need for regular daily delivery of the milk product in its freshest form is the main reason for the location of the farm and its herd in close proximity to the city market. The competition of other products for the land close to the city is keen and contributes to high values per acre. As a consequence, the dairy farmers are forced to use the high priced land for those commodities of great bulk which cannot be shipped in to the area cheaply. This was the main reason for the large proportion of pasture and roughage crops found on the dairy farms, especially in the Calgary district where yields of grain were not large and land values still relatively high. The concentrates and feeds with high value per unit bulk were imported into the area in much greater proportion than the roughages. These facts are indicated in the figures presented above.

Values of Farm Property

The relationship between the factors of production is given added significance through the index of values for land, buildings, machinery live stock and feed and seed on hand. Average total capitalization per farm on Edmonton dairy farms amounted to $19,606 as compared with $11,401 in Calgary (see Table 4). This means that Calgary dairy farmers had a much smaller investment in land and capital equipment than had the Edmonton farmers. The higher valuation was found notwithstanding the fact that the Calgary farmers produced almost as much milk per farm as those of the Edmonton district.

TABLE 4.—AVERAGE AND PERCENTAGE DISTRIBUTIONS OF CAPITALIZATION

Number of farms	Edmonton		Calgary				All farms	
	Milk shippers		Milk shippers		Producer distributors			
	40		18		9		27	
	Dollars	Per cent	Dollars	Per cent	Dollars	Per cent	Dollars	Per cent
Land	10,902	56	8,369	56	345	8	5,694	50
Buildings	4,773	24	3,231	21	2,595	61	3,020	26
Machinery	1,850	9	1,492	10	583	14	1,189	10
Live stock	1,880	10	1,796	12	713	17	1,435	13
Grain and feed on hand	201	1	92	1	4	—*	63	1
Total capitalization	19,606	100	14,980	100	4,240	100	11,401	100

* Less than ½ of 1%.

The greatest difference in values of farm property between the two districts is to be found in the value of land, although all items are higher in the Edmonton district. Naturally the higher production per acre in the northern district caused a higher land capitalization. The lower capitalization in the Calgary area was largely due to the practice among many farmers of buying rather than producing feed, thus reducing the need for heavy investment in equipment.

The proportions of land, buildings, machinery and capital valuations are also given in terms of percentages (Table 4). In the Calgary district, 76% of the total farm capitalization was in land and buildings, and in that of Edmonton, 80%. Proceeding in the records from the very small farms to the very large ones in the Calgary district, it was found that percentages of total capital valuations in land progressively increased, and in buildings progressively decreased. In Edmonton on the other hand, the percentages in land and also in buildings were not significantly different on the various sizes of farms. This was largely due to the very high values of Edmonton land near the city limits where farms were small. The high value per acre on the small farms offset the larger number of acres and left total land values nearly the same. This was not so true of Calgary where the difference in value between the land close to the city and the land at some distance is not as great.

The percentage of total capitalization in machinery is not significantly different between the Calgary and Edmonton districts. Live stock form a much higher percentage on farms up to the quarter-section size in Calgary than in Edmonton. The larger percentage of capitalization in live stock in Calgary on the smaller farms is chiefly due to lower absolute values of land and buildings than obtains in Edmonton, thus leaving larger percentage figures for the same absolute values of livestock.

In summary, it may be said that there are obvious variations in the proportions of land and capital utilized by farmers between the two major districts and also within the same districts. In a later section, analysis of

the net returns from the farm business will give a comparison of farmers using different proportions of land and capital.

Labour

On many of the dairy farms studied, labour is a relatively important item. In the Edmonton district the annual wages bill on one farm ran up to $902 as compared with $600 as the highest in Calgary. The average cash wages paid by Edmonton farmers was $265 per farm as compared with $182 per farm in the Calgary district. This would suggest a greater use of labour on the Edmonton farms than on those of Calgary, since the amount of unpaid help was approximately the same in each district. The chief reason for the difference was, of course, the lesser need for labour in the Calgary district where such a large proportion of the feed for the live stock was purchased rather than home-grown.

Management

Up to this point, the proportioning of the three factors: land, capital and labour, has been discussed. The fourth factor, management, is now to be examined. The first part deals with the tenure of operation or management of the farms and the period of occupancy. The second part deals with financial progress over the years. The third part is an evaluation of the "success" of the operators in the management of their farms during the crop year 1933–34. This is accomplished by comparison of various types of farms and farming practices in terms of their net returns (profits).

Land Tenure and Period of Occupancy

The great majority of the farm operators in this survey in both Edmonton and Calgary districts owned at least a part of their land; only four in Edmonton and two in Calgary rented all of the land they farmed. Of the remaining 36 in Edmonton, six also rented a part of their land; in Calgary, of the remaining 25, thirteen rented a part of their land. Table 5 summarizes the number of owners, owner-tenants and tenants, and also presents the average years of occupancy in the various groups.

TABLE 5.—LAND TENURE AND AVERAGE YEARS OCCUPANCY

	Edmonton			Calgary		
	Number	Average years on present farm	Range	Number	Average years on present farm	Range
			(Years)			(Years)
Owners	30	20.9	3–51	12	19.8	4–45
Owner-tenants	6	21.3	8–43	13	14.1	6–36
Tenants	4	8.2	2–13	2	6.5	3–10
All farms	40	19.5	2–51	27	15.7	3–45

The tenants were naturally the most recent settlers in the district, and their period of occupancy was much shorter than that of the owners or the owner-tenants. Tenancy allows for much greater mobility of the factors of labour, capital, and of operators with the short-term renting

contracts usually existent. This leaves room for more rapid changes in type of production than otherwise would be the case. However, as will be noticed from the table above, tenancy was not a very great factor in the milk sheds of Calgary and Edmonton. This tended to make for greater stability and inertia in the production of milk and in the combination of the factors of production than is found in many other farm areas. The Edmonton district showed less tenancy than Calgary. This is another indication of the more stable and regular nature of the production of milk in the northern area.

Financial Progress

The methods by which farm operators held their land has now been presented. This section will stress the financial progress of those operators over the years. The measuring stick is that of present net worth and the relation of assets to liabilities. Since the liabilities of farm operators have been a cause of great concern in the past few years, these are given some emphasis here. They will be shown in relation to the present farm capitalization and present statement of total assets. These liabilities have been an important factor in the financial progress of the operator and for that reason are presented first.

The high land values surrounding the two largest cities in Alberta resulted in the use of relatively large advances of credit in the buying of land. The greater use of machinery in the past decade also contributed to the use of credit. The average total indebtedness in the Edmonton district was $4,318 per farm, which was $1,433 higher than that of Calgary. Table 6 also presents the average amounts of debt against the various items

TABLE 6.—DISTRIBUTION OF INDEBTEDNESS

Type of indebtedness	Edmonton			Calgary		
	No. with debt	Average for those with debt	Average for 40 farmers	No. with debt	Average for those with debt	Average for 27 farmers
		$	$		$	$
Land	25	5,943	3,715	16	4,180	2,478
Machinery	10	448	111	4	267	40
Lumber	4	213	22	4	541	80
Other	27	697	470	20	389	288
Debt (all forms)	33	5,234	4,318	21	3,710	2,886

of security. In both Calgary and Edmonton, 86% of the total indebtedness was in mortgages and agreements of sale against real estate. Machinery, lumber, grocery bills and taxes were the other chief items of indebtedness.

Despite the higher indebtedness of Edmonton farms, a higher average equity in the farm was found, namely, $13,791 in the Edmonton district as compared with $7,163 in the Calgary district. Edmonton farmers had 76% and the Calgary farmers 71% equity in the farm (see Table 7). The equity in the farm is a part of the savings of farmers. Outside investments in stocks, bonds, real estate and the like, when added to the equity, give the net worth. It is interesting that not only had Edmonton farmers

TABLE 7.—CAPITALIZATION, INDEBTEDNESS AND EQUITY

Number of farms	Edmonton		Calgary	
	40		27	
	Dollars	Per cent	Dollars	Per cent
Operators' indebtedness	4,318	24	2,886	29
Operators' equity	13,791	76	7,163	71
Operators' capital	18,109	100	10,049	100
Landlord's capital	1,497		1,352	
Total capital	19,606		11,401	

much higher equity in their farms but also much larger outside investments averaging $1,552 per farm in Edmonton and only $145 in Calgary. Total savings, or net worth, of Edmonton farmers then were $14,171 per operator as compared with only $7,308 in Calgary. The stable nature of climatic and production conditions in the Edmonton milk shed as compared with those of Calgary has contributed largely to this great difference in the savings of the two groups of farmers.

Farm Efficiency Factors in Relation to Profit and Loss

The two previous sections have presented information on the tenure of operation and the farmers' accumulation of savings and of the factors of production over the years. Attention will now be focussed on a detailed analysis of the operations of the farmers during one year. This will be a statement of the net returns to management, *i.e.*, profit.

Details of expenses and receipts for the crop year 1933–34 were taken from the farmers interviewed. From the computation of expenses and revenue has been found the return to entrepreneurship:— profit in the business. This profit figure (or loss, as the case may be) has been considered sufficiently important to be some indication of the success or failure of farming during the year in question. For that reason, farm efficiency factors will be analysed with profit (or loss) as the chief index of success. The profit figure, since it involves certain arbitrary computations requires certain reservations. These will be stated as they arise in the analysis.

Profit is the residue of earnings which remains after all annual expenses of production are paid. These expenses of production include wages of labour[6], depreciation and repairs[7], interest on capital[8], and all of the cash costs of supplies which could not be allocated to land[9], labour, and capital. Revenue includes cash receipts from the year's production, and credits to the living of the family and to labour in the form of farm products and rent for the house[10].

The following sections present the relationships of various factors to the profits which the dairy operators received from their farms. These

[6] Includes cash wages to hired help, operator's estimate of wages for himself and for those members of the family who participated in farm work. Also includes computation of cash and non-cash costs for board.

[7] Rates of depreciation used as follows: General farm machinery, 7% and repairs 4% of inventory valuation; tractors, 11% and cash repairs; trucks, 15% and cash repairs; cars, 15% and cash repairs; buildings, 4% and repairs 1%.

[8] Actual interest payable on indebtedness and also 5% computed on the operators' equity in the farm.

[9] Cash or share rent is included.

[10] 10% of the value of the house.

include the comparisons between the milk shippers and the producer distributors, the prices received for the milk product, costs of production, sources of cash receipts, size of farm in area of land and numbers of cows in the herd, and finally the proportions of surplus milk. The operators were divided into those who made profits on the year's business and those who sustained losses. Between these two groups the above items have been compared in order to determine the more profitable farming practices on the basis of the year 1933–34.

Marketing Methods and Returns

The comparison in this section is between the milk shippers who marketed their milk at wholesale and producer-distributors who sold the retail product. Perusal of the individual records showed that in the Edmonton district, eight of the forty milk shippers had profits. In the Calgary district only one of the milk shippers showed a profit, and the remaining seventeen were in the loss column. Of the producer-distributors, all of whom were in the Calgary district, five showed profits and four losses. In Table 8, the frequency distribution of farms according to the profits received is given. It will be noticed that the milk-shippers are found in larger numbers in the negative or loss groups and the producer-distributors in the positive or profit groups. In interpreting these results, some allowance must be made for the fact that the number of farms included is not large. Moreover, in calculating profits, it is customary to adopt certain arbitrary, though accepted, standards. It is believed, however, that the sample is fairly representative, that the methods of calculation are sound, and that the results are indicative of the returns received by each group.

TABLE 8.—FREQUENCY DISTRIBUTION OF CALGARY AND EDMONTON DAIRY FARMERS ACCORDING TO PROFIT

Profit	Edmonton	Calgary	
	Milk-shippers	Milk-shippers	Producer-distributors
	No. of farms	No. of farms	No. of farms
−$1,000 or less	7	5	—
−$1,000 to −$ 500	13	3	—
−$ 500 to $ 000	12	9	4
$ 000 to $ 500	6	1	2
$ 500 to $1,000	1	—	1
$1,000 to $1,500	1	—	2
All farms	40	18	9

The difference between the producer-distributors and the milk-shippers is of sufficient magnitude to merit separate treatment in the remainder of the analysis of farm efficiency factors.

Price of Milk

Due to the policy of paying for milk on a "city-sweet" and "surplus" basis, the prices received for all milk sold by individual farmers varied considerably. A difference is also to be expected between the milk-shippers and the producer-distributors since the former sell at wholesale and the latter at retail prices. Among other things, it is noted that the average price received by all Edmonton milk-shippers (Table 9) was $1.12 per

TABLE 9.—AVERAGE DISTRIBUTION OF THE VARIOUS FACTORS ACCORDING TO PROFIT AND LOSS GROUPS

EDMONTON MILK SHIPPERS

——	No. of farms	Total profit	Profit per cwt.	Rec. per cwt.	Cost per cwt.	Rec. from milk	Rec. other than milk	Total Rec.	Size of farm ac.	No. of cows per farm	Prod'n. per cow lbs.	Milk sold cwt.	Aver. per-centage surplus	Milk test	Total capi-taliza-tion
		$	$	$	$	$	$	$						%	$
Profit group	8	444	0.23	1.17	0.94	2,235	1,725	3,960	278	23	8,055	1,737	31	3.54	17,640
Loss group	32	−706	−0.73	1.10	1.83	1,461	1,259	2,720	269	19	7,780	1,299	47	3.57	20,097
All Edmonton milk shippers	40	−476	−.53	1.12	1.65	1,616	1,352	2,968	271	20	7,835	1,414	43	3.56	19,606

CALGARY MILK SHIPPERS

Profit group	1	120	0.10	1.21	1.11	1,450	2,800	4,250	640	32	9,375	1,190	5	3.40	22,778
Loss group	17	−729	−0.46	1.11	1.57	1,831	718	2,549	355	27	6,503	1,694	39	3.56	14,520
All Calgary milk shippers	18	−682	−0.43	1.12	1.55	1,810	834	2,644	371	27	6,663	1,666	37	3.56	14,979

CALGARY PRODUCER-DISTRIBUTORS

Profit group	5	665	1.14	3.66	2.52	3,146	886	4,032	80	18	6,086	861	6	3.80	3,908
Loss group	4	−107	−0.23	3.45	3.68	1,924	525	2,449	29	13	6,682	559	7	3.90	4,656
All Calgary producer-distributors	9	322	0.53	3.57	3.04	2,602	726	3,328	57	16	6,351	727	7	3.83	4,240

hundredweight of all milk sold. The profitmakers among the milk-shippers received a higher average price ($1.17 per hundredweight) than did those with losses ($1.10 per hundredweight). This is largely due to the fact that a lower percentage of the milk sold by the first group was paid for at surplus prices. These producers also delivered milk that tested higher in butterfat content. There is little argument needed to show that higher prices were conducive to greater profits.

In the Calgary district, there was a similar relationship between prices received. The one milk shipper who made a profit received an average of $1.21 per hundredweight as compared with $1.11 per hundredweight for the loss group. Among the producer-distributors in the southern district, the profit-makers received $3.66 per hundredweight as compared with $3.45 per hundredweight for the loss group. It is significant, however, that the difference in profits was not due entirely to the difference in price. Costs of production seemed to be much more important.

Cost of Producing Milk

The cost of producing milk varies greatly in the several groups comprising this study. In Table 10, a frequency distribution of costs is presented. The large number of milk shippers had costs ranging between $1.00 and $1.49; this is the group within which the price received ranges (Table 9). The Calgary producer-distributor group, not shown in the table, had costs ranging from about $1.00 per hundredweight to $4.00.

TABLE 10.—FREQUENCY DISTRIBUTION OF MILK SHIPPERS ACCORDING TO COST PER HUNDREDWEIGHT OF MILK SOLD

Cost per cwt.	Edmonton milk shippers	Calgary milk shippers
	No.	No.
Less than $1.00	6	1
$1.00 to $1.49	15	8
$1.50 to $1.99	11	6
$2.00 to $2.49	5	3
$2.50 and over	3	—
	40	18

These costs are indicative of the efficiency of operation of the whole farm unit but are not precisely accurate measures of the efficiency of the milk enterprise except in so far as this is the major item in the operations of the farmers involved. In the method used to determine costs of the major enterprise, all supplementary products were considered as having been produced at exactly what they returned. This is a rather rough method of determining costs since it reduces or adds to the cost of the principal product by the amount of the profit or loss on the supplementary products. Although not yielding a precise cost figure, the method has considerable merit when used under conditions of production such as those prevailing in the regions under study.

The average cost per hundredweight of milk sold by the Edmonton "profit group" was $0.94 as compared with $1.83 by the "loss group" (Table 9). In the Calgary district the difference was quite apparent but not as striking as in the Edmonton district. Those making a profit had average per unit costs of $1.11 as compared with an average of $1.57 for the loss group. The profit-makers among the producer-distributors had average costs of $2.52 as compared with $3.68 among those who sustained losses. Apparently differences in cost were of much more importance than

those of prices received since the average difference between the profit and loss groups is much greater on the basis of cost than on that of price.

Sources of Cash Receipts.

Receipts from farm enterprises other than milk played an important rôle in determining the costs of milk production. Supplementary and complementary enterprises which were dovetailed into the milk business seemed to contribute, in many instances, to reducing the costs of the main enterprise of milk production. This was especially true of the milk shippers. It is very difficult, in fact well nigh impossible, to present figures which would indicate definitely the part which supplementary and complementary enterprises played in increasing the returns to the farm business as a whole. Some indication it given in the relative proportions of cash receipts which came from the sale of milk and from other sources. These, however, can be very misleading since the gross returns from an enterprise are not necessarily indicative of the profit which it adds to the business as a whole.

In the Edmonton district, both the profit and the loss group showed higher average total cash receipts from milk than from all other enterprises combined. However, the fact that $1,725 per farm was received by those showing a profit from enterprises other than milk, indicates that these men did not specialize in milk to the complete exclusion of other enterprises. Some sold breeding stock, some fed hogs, others sold large quantities of wheat and some other cereals, all of which affected the costs of milk production. Gross returns from both milk and other sources were higher for the Edmonton profit group than for the loss group.

In the Calgary district, the one producer showing a profit among the milk shippers received almost twice as much from sources other than milk. In this case, the added revenue was chiefly from hogs to which skim milk was fed. Those milk shippers in the loss group were in the opposite category, receiving more than twice as much from the milk sales as from all other sources. Apparently, then, in a dry year like that of 1933–3 when feed is scarce, those who specialized in milk with only a minimum of other enterprises, suffered accordingly. Among the producer-distributors, the milk enterprise was predominant throughout. To produce and retail milk seemed to have been a sufficient diversification of the farm business to utilize to best advantage the time of the operator.

Throughout all groups, it is significant that those with the highest gross cash receipts were the most consistent profit makers. This seems to demonstrate that size of the farm business in terms of turnover was directly related to profits.

Size of Farm Business

The average size of farm for the Edmonton milk shippers who made profits was 278 acres as compared with 269 acres for those with losses (see Table 9). The difference was not great, and therefore is inconclusive evidence of the advantage of large farms over smaller ones, especially with the wide variations in occupied acreages.

In the Calgary district, many of those who were in the loss group were on very small farms and purchased all of the fodder used. The producer-distributors in Calgary had much smaller farms than the milk shippers. Very few of the producer-distributors attempted to produce their own

fodder, some even carried on with practically no pasture land. The average occupied acreage of the producer-distributors who made profits was much higher (80 acres), than for those who made losses (29 acres). This suggests that even the producer-distributors might find it advantageous to maintain at least sufficient acreage to give adequate pasturage and at the same time provide some of the fodder for their stock.

Size of Herd, Annual Milk Production and Production Per Cow

The profits to be made in dairying seemed to have a direct relation to the size of herd kept by the farmer. In Table 9, the average size of herd for the profit and loss groups is shown. In both Calgary and Edmonton, and within the milk-shipper and producer-distributor groups in the former, those farmers showing profits had a larger average size of herd than did those with losses. This is rather significant. It does not mean that the farm operator with a small herd could not make profits, but it does indicate that the chances of making profits were greater for those with the larger herds. The advantages of the larger herds in reducing fixed costs per unit of output were rather important, at least up to a point. What that point was, varied of course with the individual farm and farmer.

In Edmonton, the milk-shippers reporting profits sold a much higher average amount of milk during the year than did those in the loss group, 1,737 cwt. as compared with 1,299 cwt. In Calgary, the one milk-shipper with a profit sold much less whole milk (1,190 cwt.) than the average of those with losses (1,694 cwt.). However, he shipped a large proportion of separated cream which accounted for an additional 1,800 cwt. of whole milk produced. This is not shown in the table (Table 9) since it was not sold as whole milk.

The average production per cow on all Edmonton farms studied was 7,835 pounds per year, that for Calgary shippers 6,663 and for Calgary producer-distributors 6,351. The explanation of the lower production in the Calgary area is probably due in part to the shortage of feed and higher prices prevailing in that area. The higher butterfat test of milk sold by producer-distributors in the Calgary area also accounts for part of the difference since the higher quality was probably obtained at the expense of total production.

However, those who made profits among the Edmonton and Calgary milk shippers each had higher average production per cow than did those who made losses. Among the Calgary producer-distributors, it is significant that the profit makers had lower producing cows than did those in the loss groups. This seems to be explainable by the fact that the producer-distributors required a high proportion of cream to milk in their bottle deliveries and were therefore encouraged to use high test rather than high milk producing cows in order to make the greatest profits.

The Effect of Surplus Milk

The number of farmers who were able to ship all of their milk at "city-sweet" prices was very small. One or two produced special milk which was all purchased at the prevailing city-sweet price. Surplus percentages for farms varied from zero to 70%. The average for all Edmonton milk-shippers was 43% and for Calgary milk-shippers was 37%.

Surplus percentages played an important role in the profits to be made on the farm through the medium of the price which the farmer received for his milk, since surplus milk was paid for by the distributors on the basis of butterfat prices. These were much lower than the city-sweet prices. It was not surprising, then, that in all groups those showing profits had a smaller percentage of surplus than those with losses. The advantage in proportion of surplus and therefore price per unit of milk lay with those producers who had continued over the years to deliver a continuous supply of milk. Unless the system of calculating surplus by the previous records of delivery is changed, the regular producer will continue to benefit.

This matter of surplus, since it so greatly affected the returns of the individual farmer, was probably one of the most important temporary problems facing these dairymen. It is doubtful whether rising demand and increasing profits from other than milk enterprises will solve the surplus difficulties entirely in the Edmonton district, although it might do so for short periods under the drier and more variable conditions of production in the Calgary district.

GENERAL ASPECTS OF PRODUCTION AND MARKETING OF MILK IN THE CALGARY AND EDMONTON MILK SHEDS

Analysis of these data has shown that the bulk of the production of fluid milk for the Calgary and Edmonton markets was done by specialists in specialized areas. It has also been shown that these specialized farmers were those who had been in the business for a relatively long period. Specialized milk production is not quickly established and the factors of production do not rapidly move out of the production of that commodity. The resultant inertia has played an important role in price fluctuations, and supply has tended to vary only slightly with changes in demand. As a consequence, prices have fluctuated quite violently, chiefly in relation to the changes in the general price level. During the period of this study, the business cycle was in its depression phase and the price of milk was relatively low.

Although production varied but little, a few farmers found it profitable to decrease their supply of whole milk and to diversify their farm business, and met with success. The most significant instance of this is the case of the one Calgary milk-shipper who made a profit by separating a part of the whole milk and shipping the cream, keeping his skim milk to feed hogs. There are some obstacles which discourage more farmers from following this practice. Regulations of the milk industry forced most farmers to maintain their full supply of whole milk in order to secure an optimum quota. It is the size of this city-sweet quota which largely determined the price of the milk product. If the quota system were not in effect, it is conceivable that many farmers would have been in a position to increase their profits by using a part of their separated milk in a supplementary enterprise such as hog feeding. There would necessarily have been repercussions on the distributors who could not count on the continuous supply of milk. Unless distributing companies can find it cheaper to buy separated cream above the city-sweet quotas and thus change the system of buying surplus, there is little likelihood of much change in the diversification of the dairy farm business.

The inertia associated with the specialized production of milk had other far-reaching effects. It caused a minimum fluctuation in land values since dairy farmers seldom give up their land even in the face of short-run losses. This tended to maintain the price of land at a long-run-level. As a consequence, the cost of land rent was relatively fixed in amount for long periods of time and price of the milk product only affected it in the very long-time period. It tended to increase the losses when farmers were under long-time contracts in renting or buying land. This problem is necessarily related to the mortgage and general land debt question, which in turn has important effects on the purchasing power of the farmer. The fluctuations in the price which the farmer receives for his products in relation to fixed charges represented by interest and principal payments are a matter of major concern. Increased mobility of the factors of production would expedite the adjustment of the prices received by the farmers as well as the costs entailed in production, especially land rent and mortgage payments. This would involve greater mobility of the people as well. The advisability of decreased specialization and increased mobility of the factors of production is a question which those in the industry must decide for themselves.

In order to obviate the difficulties involved in the movement of people and the factors of production as a means of adjusting the price of milk, the government placed the fixing of price and the control of producers, retail and wholesale, under the Public Utilities Commission. This occurred in 1932. The Commission from that time forward fixed wholesale and retail prices and licensed all producers. Through this means, they regulated the price and also the number of producers. It is too early yet to estimate the effects of this policy on the production and marketing of milk.

Résumé

La production du lait en nature dans les vacheries d'Edmonton et de Calgary. G. H. Craig, J. Proskie, et V. A. Wood, Université de l'Alberta, Edmonton, Alta.

L'analyse de ces données démontre que la majeure partie du lait destiné à la vente en nature, sur les marchés de Calgary et d'Edmonton, est produit par des spécialistes, dans des régions spécialisées. Elle montre également que ces cultivateurs laitiers sont dans l'industrie depuis un temps assez long. La production spécialisée du lait n'est pas une industrie d'établissement rapide, et l'on ne peut pas non plus en sortir rapidement. L'inertie qui en résulte a joué un rôle important dans les fluctuations des prix, et la quantité de lait offerte ne varie que légèrement avec la demande. Il en est résulté de violentes fluctuations de prix réfléchissant les changements notés dans le niveau général des prix. Pendant la période couverte par cette étude, le cycle des affaires était dans sa phase de dépression, et le prix du lait était relativement bas.

Certains cultivateurs ont trouvé avantageux de réduire leur production de lait entier et de diversifier leur exploitation agricole. L'exemple le plus significatif est celui d'un expéditeur de lait de Calgary qui a fait un bénéfice en écrémant une partie du lait entier et en expédiant la crème, gardant son lait écrémé pour alimenter ses porcs. Cependant cette pratique présente certains inconvénients qui s'opposent à son adoption plus générale. La réglementation de l'industrie du lait a obligé la plupart des cultivateurs à maintenir toute leur production de lait entier, afin d'obtenir un meilleur contingentement. C'est, en effet, l'importance du contingentement des

villes qui détermine en grande partie le prix du lait. Si ce système de contingentement n'était pas appliqué, il est possible que beaucoup de cultivateurs auraient été en mesure d'augmenter leurs bénéfices en utilisant une partie de leur lait écrémé dans une industrie annexe, comme celle de l'engraissement des porcs. Cette situation aurait eu naturellement sa répercussion sur les laitiers, qui ne pourraient compter sur la provision régulière de lait. Il n'est donc guère probable que l'industrie laitière sur la ferme connaisse de grands changements, à moins que les compagnies de distribution ne trouvent qu'il est plus économique d'acheter la crème séparée, en dehors du contingentement du lait frais et de modifier ainsi le système d'achat du surplus.

L'inertie qui se rattache à la production spécialisée du lait a eu d'autres effets très importants. Elle a réduit au minimum la fluctuation dans la valeur des terres, car les cultivateurs laitiers abandonnent rarement leurs terres, même pendant une période de déficit, et c'est pourquoi le prix de la terre est demeurée longtemps au même point. Il en est résulté que le prix du loyer de la terre est resté relativement fixe pendant de longues périodes de temps et n'a été affecté qu'au bout d'un très long temps par le prix du lait. Les pertes ont été plus fortes pour les cultivateurs qui avaient conclu un contrat à long terme pour la location ou l'achat de la terre. Ce problème se rattache nécessairement à la question de l'hypothèque et de la dette générale de la terre, qui a exercé à son tour un effet important sur la puissance d'achat du cultivateur. Les fluctuations qui se produisent dans le prix que le cultivateur reçoit pour ses produits par rapport aux frais fixes, représentés par l'intérêt et l'amortissement du principal, sont une question d'intérêt primordial. Une mobilité plus grande des facteurs de production faciliterait l'alignement des prix reçus par les cultivateurs, de même que les frais de production, spécialement le loyer des terres et les paiements sur les hypothèques. Ceci entraînerait également une plus grande mobilité de la population. La question de savoir s'il y aurait avantage à décroître la spécialisation et à agrandir la mobilité des facteurs de production est un problème qui devrait être résolu par ceux-là mêmes qui s'occupent de l'industrie.

Pour obvier aux inconvénients qu'entraînerait le mouvement de la population et des facteurs de production comme moyen d'aligner le prix du lait, le gouvernement a confié en 1932 la question de la fixation du prix et du contrôle des producteurs, du gros et du détail, à la Commission des utilités publiques. A partir de 1932, la Commission a fixé les prix de détail et de gros et a licencié tous les producteurs. Elle a réglé par ce moyen le prix ainsi que le nombre de producteurs. Il est encore trop tôt pour évaluer les effets de cette décision sur la production et la vente du lait.

33256—2½

THE EFFECT OF FREEZING TEMPERATURES AND OF DEFOLIATION ON THE SUBSEQUENT GROWTH OF WHEAT PLANTS[1]

A. W. Platt[2]

University of Alberta, Edmonton, Alta.

[Received for publication February 2, 1937]

INTRODUCTION

In the cereal breeding work at the University of Alberta the question arose as to whether or not consideration should be given to the reaction of spring grains to spring frosts. Investigations were undertaken to obtain information in this regard. Those described herein were concerned with the effect of injuries in the seedling stages caused by freezing temperatures and artificial defoliation on the subsequent fertile culms, heights and growth periods of wheat plants. The results of studies on the reaction of certain wheat, oat and barley varieties to freezing temperatures, and studies on certain environmental factors that might be expected to influence such reactions will be reported in a later paper (4).

EXPERIMENT 1

Methods

A refrigerating chamber 9 feet by 10 feet by 6.5 feet high was used to obtain the low temperatures desired. The temperature was controlled by means of a thermoregulator which allowed a variation of about 1.5° C.

Five varieties of spring wheat, namely, Garnet, C.A.N.[3] 1316, Reward C.A.N. 1509, Red Bobs 222, C.A.N. 1637, Marquis C.A.N. 1621 and Canus C.A.N. 1260 were used.

The first group of plants used was treated in the following manner. They were grown in 6-inch flower pots on a fertile black loam soil. Five seeds were planted in each pot, and on emergence the plants were thinned to a uniform stand of three per pot. When they reached the two-leaf stage they were divided into two lots. One lot was again sub-divided into four sub-lots. One sub-lot was left as a non-injured check; two sub-lots were exposed to freezing temperatures, the first at −8° C. for four hours and the second at −12° C. for four hours; and the fourth sub-lot was clipped off about one-half inch above the surface of the soil. It was desired to injure all varieties to approximately the same degree in order to make certain comparisons that will be discussed later. As a result, it was necessary to select plants having the required amount of injury from each of the varieties used. Plants having up to 50% of their foliage injured were designated as lightly frozen, while those having more than 50% of their foliage injured were designated as severely frozen. All plants within

[1] Contribution from the Department of Field Crops. This paper was constructed from a part of a thesis presented to the University of Alberta in partial fulfilment for the degree of Master of Science.

[2] Formerly graduate student at the University of Alberta, Edmonton, now assistant in cereal and forage crop breeding at the Dominion Experimental Station, Swift Current, Saskatchewan.

[3] Canadian Accession Number.

each of these categories were assumed to have suffered approximately the same degree of injury. When the second lot reached the five-leaf stage it was treated in the same manner as the first, and the frozen plants were similarly selected and classified. All the material was allowed to grow to maturity in the greenhouse.

The second group of plants used in this experiment was grown in wooden flats. These flats were divided into compartments by bottomless cardboard boxes which were two inches square and extended to the bottom of the flat. One plant was grown in each compartment. The plants were frozen and defoliated in the two- and five-leaf stages, as described above, and the frozen plants were similarly selected. At the time of selection all plants were transplanted to the field into rows one foot apart, and two inches apart within the rows. The cardboard containers made it possible to lift out the plants, with the surrounding soil, and place them in the field without disturbing them to any extent. The only sign of injury observed was in certain plants transplanted in the five-leaf stage where the roots had run along the bottom of the flat and consequently were broken off in transplanting. In all, over 4,000 plants were so transplanted and, by actual count, 100% survived. The check lot of plants appeared to suffer more after transplanting than did the defoliated or severely frozen plants, probably as a result of their greater foliage development. Weather conditions were ideal at the time of transplanting, and this probably accounts to a large extent for the good results obtained.

It should be noted that when the plants were grown to maturity in the greenhouse, all were under similar environmental conditions at all times, but that this was not so when the plants were transplanted to the field, as those injured in the five-leaf stage remained in the greenhouse for some time after those injured in the two-leaf stage had been removed to the field.

The date of heading, the height at maturity and the number of fertile culms per plant were recorded for each individual plant. The yield was not recorded as the grain from the material grown in the field was so badly damaged by fall frosts that yield data would have been valueless.

Results

Days from Emergence to Heading

The data obtained on the days from emergence to heading of injured and non-injured plants grown in the field and in the greenhouse are presented in Table 1. In all cases the injured plants were later in heading than were the non-injured plants and these differences are statistically significant. Among the injured groups those severely frozen were in general the latest in heading. In all cases they were later than the lightly frozen plants and, except for the Marquis and Canus plants injured in the two-leaf stage and grown in the field, they were significantly later than the defoliated plants. On the average the defoliated plants were later than the lightly frozen plants, but in many individual instances this was not the case, particularly among plants injured in the two-leaf stage and grown in the greenhouse. In most instances, the differences between groups, especially the differences between the non-injured and the injured groups, were accentuated when the plants were grown to maturity in the greenhouse as compared with

the differences obtained when the plants were grown to maturity in the field. However, the relative differences between groups grown in the greenhouse and those grown in the field are quite consistent. The plants injured in the five leaf stage were, relative to the checks, about one to two days later than those injured in the two-leaf stage.

TABLE 1.—DAYS FROM EMERGENCE TO HEADING OF WHEAT PLANTS INJURED IN THE SEEDLING STAGE BY FROST AND BY DEFOLIATION

Variety	Stage at which plants were injured	Type of injury	Days from emergence to heading					
			Greenhouse			Field		
			No. of plants	Mean	S.E. of mean	No. of plants	Mean	S.E. of mean
Garnet	2-leaf stage	No injury	60	36.17	0.24	32	44.34	0.36
		Light frost	36	40.69	0.44	102	45.48	0.27
		Foliage removed	30	41.37	0.43	55	51.05	0.25
		Severe frost	45	47.82	0.66	88	53.59	0.29
	5-leaf stage	No injury	60	36.17	0.26	58	40.40	0.13
		Light frost	25	41.96	0.77	68	41.26	0.32
		Foliage removed	30	45.40	0.53	36	44.36	0.52
		Severe frost	27	50.00	1.07	40	51.85	0.80
Reward	2-leaf stage	No injury	59	35.44	0.16	26	44.11	0.34
		Light frost	67	41.21	0.39	107	45.99	0.22
		Foliage removed	30	40.63	0.40	45	49.39	0.20
		Severe frost	49	47.12	0.56	90	51.06	0.26
	5-leaf stage	No injury	59	35.44	0.16	87	41.21	0.13
		Light frost	40	42.13	0.31	84	42.54	0.31
		Foliage removed	30	42.67	0.39	46	46.96	0.41
		Severe frost	35	47.11	0.54	41	49.51	0.55
Red Bobs 222	2-leaf stage	No injury	60	37.92	0.19	28	49.89	0.31
		Light frost	36	42.19	0.34	125	51.56	0.23
		Foliage removed	30	42.77	0.26	64	52.05	0.21
		Severe frost	47	49.79	0.70	40	55.63	0.29
	5-leaf stage	No injury	60	37.92	0.19	58	46.84	0.34
		Light frost	51	41.82	0.41	106	48.25	0.28
		Foliage removed	30	43.77	0.23	28	52.00	0.25
		Severe frost	24	51.92	0.98	14	54.86	0.71
Marquis	2-leaf stage	No injury	60	43.00	0.20	31	52.48	0.26
		Light frost	39	44.97	0.38	148	54.59	0.16
		Foliage removed	30	48.07	0.67	64	57.67	0.29
		Severe frost	29	52.62	1.09	60	58.02	0.22
	5-leaf stage	No injury	60	43.00	0.20	67	51.73	0.19
		Light frost	49	46.82	0.47	79	53.42	0.28
		Foliage removed	30	48.77	0.42	41	57.63	0.33
		Severe frost	6	56.17	1.03	41	58.98	0.45
Canus	2-leaf stage	No injury	59	43.12	0.12	34	50.56	0.31
		Light frost	60	46.08	0.31	132	53.34	0.15
		Foliage removed	30	47.33	0.63	45	55.53	0.37
		Severe frost	30	51.10	0.55	66	56.09	0.28
	5-leaf stage	No injury	59	43.12	0.12	62	49.18	0.33
		Light frost	62	46.23	0.33	92	52.51	0.26
		Foliage removed	28	49.89	0.38	36	54.61	0.44
		Severe frost	7	53.14	1.97	31	58.13	0.77

TABLE 2.—HEIGHT IN CENTIMETRES AT MATURITY OF WHEAT PLANTS INJURED IN THE SEEDLING STAGE BY FROST AND BY DEFOLIATION

Variety	Stage at which plants were injured	Type of injury	Height in cm.					
			Greenhouse			Field		
			No. of plants	Mean	S.E. of mean	No. of plants	Mean	S.E. of mean
Garnet	2-leaf stage	No injury	57	67.63	1.00	32	82.77	1.42
		Light frost	34	77.59	1.65	102	92.64	0.84
		Foliage removed	27	68.44	2.04	55	82.14	1.45
		Severe frost	26	76.24	2.09	89	79.05	1.21
	5-leaf stage	No injury	57	67.63	1.00	58	72.06	1.03
		Light frost	18	77.65	2.56	71	73.74	1.24
		Foliage removed	18	75.01	2.07	36	59.82	2.26
		Severe frost	15	70.00	3.14	40	69.00	1.70
Reward	2-leaf stage	No injury	60	75.00	1.08	25	86.16	2.13
		Light frost	29	71.79	1.15	108	92.55	0.72
		Foliage removed	29	61.77	1.42	46	78.45	1.61
		Severe frost	49	61.29	1.50	92	83.49	1.22
	5-leaf stage	No injury	60	75.00	1.08	88	69.81	1.02
		Light frost	39	66.09	1.49	86	72.42	0.78
		Foliage removed	29	55.86	1.54	45	66.12	1.34
		Severe frost	30	65.61	1.86	43	66.84	1.69
Red Bobs 222	2-leaf stage	No injury	60	81.34	1.32	28	92.46	1.39
		Light frost	35	78.82	1.69	125	90.45	1.01
		Foliage removed	30	71.59	1.59	64	99.24	0.97
		Severe frost	37	76.57	1.56	40	92.19	1.51
	5-leaf stage	No injury	60	81.34	1.32	59	81.42	1.12
		Light frost	49	75.13	1.70	117	81.12	0.83
		Foliage removed	30	73.09	2.04	30	79.50	1.72
		Severe frost	17	77.23	4.30	14	77.79	2.87
Marquis	2-leaf stage	No injury	60	86.41	1.22	31	95.52	1.55
		Light frost	42	83.20	1.09	148	99.64	0.85
		Foliage removed	30	82.99	1.76	66	94.05	1.22
		Severe frost	26	82.36	2.69	60	93.36	1.13
	5-leaf stage	No injury	60	86.41	1.22	66	72.27	1.12
		Light frost	52	86.89	1.02	79	79.26	1.01
		Foliage removed	30	82.40	1.19	42	76.35	0.64
		Severe frost	9	77.32	4.11	43	82.26	1.19
Canus	2-leaf stage	No injury	60	84.56	1.11	34	87.87	2.01
		Light frost	63	82.70	0.91	134	98.22	0.62
		Foliage removed	30	86.20	1.44	46	90.12	1.28
		Severe frost	28	75.00	1.48	65	97.44	0.94
	5-leaf stage	No injury	60	84.56	1.11	64	81.06	1.02
		Light frost	59	82.64	0.79	100	76.77	0.97
		Foliage removed	27	80.90	1.76	37	80.43	1.70
		Severe frost	13	76.07	2.67	32	78.39	1.68

Height

The data obtained on the height of injured and non-injured plants grown in the field and in the greenhouse are presented in Table 2. In the majority of instances, the differences between the mean heights of

any two groups of plants were less than 10 centimetres in extent, and only two of these exceeded 14 centimetres. No apparent relationship for all varieties and conditions was apparent between height at maturity and injury in the seedling stage. With the exception of the Garnet plants,

TABLE 3.—NUMBER OF FERTILE CULMS PER PLANT OF WHEAT PLANTS INJURED IN THE SEEDLING STAGE BY FROST AND BY DEFOLIATION

Variety	Stage at which plants were injured	Type of injury	Fertile culms per plant					
			Greenhouse			Field		
			No. of plants	Mean	S.E. of mean	No. of plants	Mean	S.E. of mean
Garnet	2-leaf stage	No injury	59	2.02	0.12	32	3.69	0.22
		Light frost	30	1.93	0.19	102	5.43	0.19
		Foliage removed	29	2.83	0.16	55	2.73	0.14
		Severe frost	31	2.35	0.18	88	3.15	0.12
	5-leaf stage	No injury	59	2.02	0.12	58	3.55	0.17
		Light frost	21	2.57	0.19	71	3.31	0.14
		Foliage removed	26	2.92	0.24	36	2.33	0.17
		Severe frost	17	2.12	0.34	40	2.30	0.17
Reward	2-leaf stage	No injury	60	2.98	0.11	26	4.15	0.32
		Light frost	29	2.41	0.20	107	4.81	0.16
		Foliage removed	29	2.34	0.21	46	3.63	0.12
		Severe frost	46	1.80	0.14	85	2.85	0.11
	5-leaf stage	No injury	60	2.98	0.11	88	3.38	0.13
		Light frost	39	2.59	0.16	85	3.34	0.12
		Foliage removed	29	2.90	0.22	46	2.59	0.16
		Severe	31	1.84	0.19	43	2.47	0.17
Red Bobs 222	2-leaf stage	No injury	59	1.64	0.08	28	6.18	0.33
		Light frost	34	1.59	0.12	125	4.93	0.16
		Foliage removed	30	1.50	0.17	64	5.17	0.21
		Severe frost	46	1.72	0.13	40	3.80	0.23
	5-leaf stage	No injury	59	1.64	0.08	59	4.78	0.23
		Light frost	50	1.64	0.09	117	4.64	0.18
		Foliage removed	30	1.67	0.13	30	3.87	0.26
		Severe frost	22	1.36	0.15	14	3.00	0.41
Marquis	2-leaf stage	No injury	59	2.27	0.11	31	4.97	0.40
		Light frost	42	2.07	0.15	138	5.64	0.20
		Foliage removed	30	2.20	0.15	66	3.74	0.17
		Severe frost	55	2.33	0.14	60	3.33	0.25
	5-leaf stage	No injury	59	2.27	0.11	67	4.19	0.22
		Light frost	51	2.04	0.13	79	5.18	0.25
		Foliage removed	29	2.07	0.11	41	3.85	0.26
		Severe frost	12	1.42	0.24	43	4.56	0.31
Canus	2-leaf stage	No injury	60	2.17	0.09	34	7.74	0.63
		Light frost	55	2.27	0.15	134	6.06	0.21
		Foliage removed	30	1.97	0.13	46	4.96	0.33
		Severe frost	33	2.03	0.18	65	5.11	0.20
	5-leaf stage	No injury	60	2.17	0.09	64	4.92	0.25
		Light frost	62	1.98	0.09	100	4.17	0.16
		Foliage removed	29	2.34	0.18	37	4.11	0.24
		Severe frost	14	1.86	0.23	32	3.78	0.41

there is a tendency for the frozen and defoliated plants to be shorter than the non-injured plants when they were grown to maturity in the greenhouse. The lightly frozen plants when grown in the field showed a tendency to be taller than the non-injured plants. The defoliated and severely frozen plants grown in the field failed to show any tendency to be generally shorter or taller than the non-injured plants.

Fertile Culms per Plant

The data obtained on the number of fertile culms per plant of material grown in the field and in the greenhouse are presented in Table 3. When plants were grown to maturity in the greenhouse there was, for the most part, little difference in the mean number of fertile culms per plant between any of the groups studied. As three plants were grown in each 6-inch flower pot, it is believed that one or more soil nutrients became limiting to such an extent that this factor was of greater importance in determining the number of culms per plant than were the treatments to which the plants were subjected. This belief is strengthened by the fact that there were practically no varietal differences between the means of check lots under these conditions, while under normal conditions such differences would be expected and were, in fact, observed when the plants were matured in the field. The defoliated and severely frozen plants grown in the field. had, with the exception of the defoliated Reward plants injured in the two-leaf stage, and the defoliated and severely frozen Marquis plants injured in the five-leaf stage, a smaller number of fertile culms per plant than had the non-injured plants. The lightly frozen Garnet plants injured in the two-leaf stage had more fertile culms per plant than had the comparable non-injured plants; while those of Red Bobs 222 injured in the two-leaf stage and those of Canus injured in the two- and the five-leaf stages had, on the other hand, fewer fertile culms per plant than the comparable non-injured plants; and in all other cases the differences noted were not statistically significant. The diminution in number of fertile culms per plant sustained by the injured plants did not appear to be consistently influenced by the stage of development at which the injury occurred.

EXPERIMENT 2

Methods

The second experiment was concerned with a comparison of defoliated and normal plants grown under field conditions and was carried out to serve as a check upon the results obtained with individual plants. The five varieties used in the first experiment were grown in five row plots, the rows being 18 feet long and 1 foot apart. The young plants were subjected to three treatments. One lot was left as a non-injured check, a second was defoliated at the two-leaf stage, and a third was defoliated at the five-leaf stage. Each treatment was in quadruplicate. The height at maturity, growth period, and yield of each plot was recorded.

Results

A summary of the data obtained on the heights, growth periods and yields of defoliated and normal plants grown under field conditions is presented in Table 4. The defoliated plants suffered a significant average

TABLE 4.—HEIGHT, GROWTH PERIOD AND YIELD OF NORMAL AND DEFOLIATED WHEAT VARIETIES

Variety	Height in cms.			Growth period in days			Yield in bus. per acre		
	Normal	Defoliated in the 2-leaf stage	Defoliated in the 5-leaf stage	Normal	Defoliated in the 2-leaf stage	Defoliated in the 5-leaf stage	Normal	Defoliated in the 2-leaf stage	Defoliated in the 5-leaf stage
Garnet	109.8	111.3	100.5	95.0	98.3	100.0	40.0	39.3	40.3
Reward	110.3	111.3	105.8	97.0	100.5	101.0	36.8	33.3	30.9
Red Bobs 222	116.5	108.0	106.8	99.0	101.3	102.5	44.0	38.3	36.0
Marquis	119.3	110.8	111.3	102.0	103.8	108.0	38.9	36.3	37.4
Canus	115.5	103.8	107.5	102.3	105.0	108.8	42.5	37.9	35.3
Average	114.3	109.0	106.4	99.1	101.8	104.1	40.4	37.0	36.0

The standard errors of the differences between the means of any two treatments are 1.5 cms., 1.4 days. and 0.7 bus. for height, growth period and yield respectively.

reduction in height of 5.5 cms. after defoliation in the two-leaf stage, and of 8.1 cms. after defoliation in the five-leaf stage when compared with normal plants. The reduction suffered by plants defoliated in the five-leaf stage was significantly greater than that suffered by plants defoliated in the two-leaf stage. The defoliated plants were significantly later in maturing than were the normal plants. On the average, those defoliated in the two-leaf stage were about three days, and those defoliated in the five-leaf stage about five days later than were the normal plants. The plants defoliated in the five-leaf stage were significantly later than those defoliated in the two-leaf stage. This retardation in the maturing of defoliated plants grown under field conditions is but slightly less than the retardation in heading of defoliated plants grown in the greenhouse or of those transplanted to the field. The plants defoliated in the two-leaf stage suffered, on the average, a significant decrease in yield of 3.4 bushels, and those defoliated in the five-leaf stage a significant decrease of 4.4 bushels per acre when compared with normal plants. The yield differences between plants defoliated in the two- and those defoliated in the five-leaf stage are not statistically significant. Unfortunately, data on yield per plant of the plants transplanted to the field are not available for comparison with these results. It will be recalled, however, that in the transplanting experiment, defoliation, in almost every instance, resulted in a reduction in the number of fertile culms per plant. If it is assumed that yield is correlated with number of fertile culms per plant, the results obtained in these two experiments are essentially similar.

Differential Ability of Varieties to Recover from Frost Injury in the Seedling Stage

It has been observed by several investigators (2, 3, 6) that the subsequent growth of susceptible varieties is affected to a greater extent than is that of resistant varieties when exposed to the same freezing temperature. This may be due to the lesser amount of injury that would be suffered by the resistant varieties or to inherent differences in ability to recover being associated with differences in cold resistance. The varieties used in this experiment suffered approximately the same degree of frost injury, consequently observations recorded on their subsequent growth should provide some evidence in this regard.

The most outstanding difference in recovery noted was that the injured Garnet plants were relatively later in maturing than were those of the other varieties, particularly those of Marquis and Canus (Table 1). These same Garnet plants, however, together with the Marquis plants, suffered relatively less reduction in height or in fertile culms per plant than did those of the other varieties (Tables 2 and 3). As Reward, Garnet and Marquis were relatively frost susceptible, while Red Bobs 222 and Canus were relatively frost resistant, it is obvious that no definite relationship between frost resistance and recovery from frost damage existed among the varieties tested when the degree of frost injury was the same for all. Nevertheless, these results indicate that the ultimate degree of injury to plant growth that may be expected due to frost injury, depends not only upon the degree of frost injury but also upon the variety injured.

These latter differences while interesting from a physiological standpoint, are probably not important from a plant breeding standpoint, as recovery from a naturally occurring frost would depend more upon the resistance or susceptibility of the variety concerned than upon the differences referred to. In any case the testing of the actual recovery made by individual varieties or hybrid lines would be impractical, while the determination of their relative frost resistance would be comparatively simple.

DISCUSSION

Waldron (6, 7) observed wheat plants and Harrington (2) observed wheat, oat, barley and flax plants after a naturally occurring spring frost, and found that the frost-injured plants suffered a reduction in yield as compared with the non-injured adjacent plants. Rzhavitin (5) subjected flax and Ivanov (3) various small grains to freezing temperatures and found that the yields of the injured plants were lower than those of the non-injured plants. The results obtained in the present investigation are not conclusive but seem to support the contention that seedling frost injury reduces the subsequent grain yield. In practically all cases the plants severely injured by low temperatures had fewer fertile culms per plant than did the non-injured plants. Waldron's data (7) show that the yield per culm of injured plants was lower than the yield per culm of non-injured plants. If such is the case in the present investigation, the decrease in the yield per plant would be greater than the decrease in the number of fertile culms per plant would indicate. The reduction in yield per plant under the conditions of this experiment does not necessarily mean that a reduction in yield per acre would occur with a similar amount of injury under field conditions. In fact, when the amount of nutrients per plant was extremely limited, as when the plants were grown to maturity in pots, the majority of the injured plants failed to show a reduction in the number of fertile culms when compared with the non-injured plants. Such a reaction might be expected under certain field conditions. On the other hand, a definite reduction in yield per acre, due to defoliation, was obtained in the field. Furthermore, this reduction was at least somewhat comparable to the reduction in fertile culms per plant of the defoliated plants growing under conditions similar to those which obtained for the severely frozen plants. These results appear to support the contention that frost injury in the seedling stage does cause a reduction in yield per acre under field conditions.

The results obtained with regard to the influence of seedling injury on the resulting plant height indicate that any differences in height, attributable to this factor, are not of sufficient magnitude to be of any significance in commercial wheat production. The great variability obtained in the differences in height of injured and non-injured plants provides evidence that, in addition to seedling injury, other factors were exerting a marked influence on this character.

Seedling injury, due to frost or defoliation, appears to increase definitely the growth period of the plants so injured. In areas such as west central and northern Alberta this lengthening of the growth period is of paramount importance in that it increases the hazard of fall frosts which substantially reduce both the yield and the grade of the grain. An increase of about nine days in the growth period may be expected when plants are severely frosted. Such an increase would in many years, in such areas as have been

mentioned, doom the crop to exposure to fall frosts previous to maturity with all the loss that this occasions, aside from any loss in yield that the seedling injury in itself may have caused. It is recognized that the delay observed in the maturing of injured plants in these experiments may not be comparable with that obtained in the field. The only check available is that obtained between the defoliated plants growing under field conditions and those growing under conditions similar to the frosted plants. In this comparison the delay occasioned in each instance was of approximately the same duration.

It should be kept in mind that in all cases the injured plants in these experiments developed under conditions very favorable to recovery. Had less favorable conditions prevailed, the results might have been vastly different. Nevertheless it seems probable that had conditions been less favorable, due to drought or similar factors, the injured plants would have suffered as much or possibly more, relative to the checks, than they did actually.

SUMMARY

Five varieties of spring wheat were injured in the two- and in the five-leaf stage by frost and defoliation. One lot of material was allowed to grow to maturity in the greenhouse and one was transplanted to the field shortly after being exposed to freezing temperatures, and allowed to grow to maturity. On the average, the lightly frozen plants were about five days later and the severely frozen plants about nine days later in heading than were the non-injured plants. The differences in days from emergence to heading were accentuated when the plants were grown to maturity in the greenhouse (compared with the differences obtained when the plants were grown to maturity in the field). The plants injured in the five-leaf stage were about two days later in heading than plants injured to the same degree in the two-leaf stage. The height of injured plants at maturity was found to be not greatly different from that of non-injured plants. The number of fertile culms per injured plant was approximately the same as the number per non-injured plant when grown in the greenhouse, presumably under conditions of a very limited nutrient supply. When, however, the plants were grown in the field, and having presumably a more generous nutrient supply, those severely injured by frost showed a reduction in fertile culms per plant of approximately 30%, and those defoliated a reduction of approximately 20%, when compared with non-injured plants.

Under normal field conditions plants defoliated in the two- and in the five-leaf stages were found to be significantly later in maturing, lower in height and in yield per acre than were the normal plants.

There was some evidence that varietal differences in the ability to recover from the same degree of frost injury may exist. Among the varieties tested such differences were not associated with frost reaction.

ACKNOWLEDGMENTS

The author wishes to acknowledge his indebtedness to Dr. O. S. Aamodt, Chairman of the Department of Agronomy, University of Wisconsin, Madison, U.S.A., who suggested this topic for investigation, and to Dr. K. W. Neatby, Professor of Genetics and Plant Breeding, University of Alberta, Edmonton, for his assistance in the preparation of the manuscript.

LIBRARY
PURDUE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION

REFERENCES

1. Fisher, R. A. Statistical Methods for Research Workers. 4th Ed. Oliver and Boyd, Edinburgh. 1932.

2. Harrington, J. B. The effect of spring frosts on the yields of spring sown grain. Sci. Agric. 16 : 538-548. 1936.

3. Ivanov, S. M. The response of spring crops to spring frosts. Bull. Appl. Bot. Gen. Pl. Breed. Ser. 3 : 199-220. 1935. Russian with English summary.

4. Platt, A. W. The reaction of certain cereals to freezing temperatures. (Unpublished data.)

5. Rzhavitin, V. N. Resistance of different flax varieties to spring frosts and the influence of the latter on growth, development and yield of flax. Bull. Appl. Bot. Gen. Pl. Breed. Ser. 3 : 227-234. 1935. In Russian with English summary.

6. Waldron, L. R. Frost injury to spring wheat with a consideration of drought resistance. Jour. Amer. Soc. Agron. 23 : 625-637. 1931.

7. Waldron, L. R. Differences of injury by frost to wheat plants grown comparably. Jour. Amer. Soc. Agron. 24 : 494-500. 1932.

Résumé

L'effet de la gelée et de la défeuillaison sur la végétation ultérieure des plants de blé. A. W. Platt, Université de l'Alberta, Edmonton, Alta.

Cinq variétés de blé de printemps, qui étaient à la phase de deux feuilles et de cinq feuilles, ont été abimées par la gelée et la défeuillaison. On a laissé un lot de matériaux pousser jusqu'à maturité complète dans la serre, tandis qu'un autre était transplanté dans le champ, peu après avoir été exposé à des températures de congélation, et il s'y est développé jusqu'à maturité. En moyenne, les plants légèrement gelés ont épié environ cinq jours plus tard, et les plants gravement gelés environ neuf jours plus tard, que les plants non endommagés. La différence en jours entre la levée et l'épiage était accentuée lorsque les plants étaient cultivés jusqu'à maturité dans la serre (par comparaison aux différences notées quand les plants étaient cultivés jusqu'à maturité dans le champ). Les plants abîmés alors qu'ils étaient à la phase de cinq feuilles ont épié environ deux jours plus tard que les plants abîmés au même degré dans la phase de deux feuilles. On a constaté que la hauteur, à maturité, des plants endommagés ne différait pas beaucoup de celle des plants non endommagés. Le nombre de tiges fertiles par plant endommagé était à peu près le même que le nombre par plant non endommagé, lorsque la culture se faisait en serre, dans des conditions où la provision d'éléments nutritifs paraissait être très limitée. Cependant quand on cultivait des plants dans le champ, où la provision d'éléments nutritifs était plus généreuse, les plants qui étaient gravement endommagés par la gelée accusaient une réduction d'à peu près 30 pour cent de tiges fertiles par plant, et ceux qui étaient défeuillés, une réduction d'environ 20 pour cent par comparaison aux plants non endommagés. Dans les conditions normales de grande culture, on a constaté que les plants défeuillés dans les phases de deux et de cinq feuilles étaient beaucoup plus lents à mûrir; ils étaient aussi moins élevés et rapportaient moins par acre que les plants normaux. Certaines preuves indiquent qu'il peut y avoir des différences entre les variétés au point de vue de l'aptitude à se remettre du même degré de gelée. Ces différences ne se rattachaient pas à la réaction à la gelée parmi les variétés essayées.

THE SEED VALUE OF FROSTED WHEAT[1]

N. G. Lewis[2] and A. G. McCalla[3]

[Received for publication February 25, 1937]

INTRODUCTION

The frequency with which a portion of the wheat crop of Western Canada is frozen before reaching maturity makes the appraisal of seed value of frozen wheat a recurring problem. Following such years as 1928, 1934 and 1935 the Seed Branch of the Dominion Department of Agriculture is called upon to test and grade hundreds of samples of wheat damaged to varying degrees by frost. In 1928 this organization began laboratory and field studies in an effort to obtain information which would improve the standard of grading such wheat for seed purposes.

About the same time the Associate Committee on Grain Research had undertaken a study of the effect of frost on the milling and baking quality of wheat. In order to determine the factors contributing to frost injury it was necessary to study material of known history, and a refrigeration plant was installed at the University of Alberta for the purpose of producing such material. The results of physical, chemical and milling and baking tests have been published by Newton and McCalla (10).

It was suggested that the material produced for these studies would be useful in an investigation tracing the factors causing injury to wheat as seed. The Seed Branch undertook to supervise such an investigation. This paper deals with the results obtained with the samples produced in 1930 and 1932, and with those of two preliminary experiments carried out with samples of unknown history.

PREVIOUS WORK

Most of the literature dealing with the effect of frost on seed germination was published before 1931. The early investigations were principally concerned with the relation between the blotter test results and field trials. The shortcomings of the blotter test, in which all seedlings were counted regardless of whether they were strong or weak, were recognized by seed analysts (5). In an effort to remedy the defects of the blotter test, and at the same time to maintain standard methods among international seed testing stations, a more severe type of test, in which only normal seedlings were counted, has been tried (6). By this test, many abnormal seedlings, which may still be capable of producing normal plants in the field, are eliminated. Some of the later literature deals with the interpretation of tests on the basis of seedling type and survival.

That germination of many types of seeds in the field is usually lower than that in the laboratory has been reported by many investigators. Wright (15) found that oats germinating between 70 and 100% in the laboratory averaged 10% lower in the field, while those germinating below

[1] Contribution from the Seed Branch, Dominion Department of Agriculture and the Department of Field Crops, University of Alberta. The material studied was produced with financial assistance from the National Research Council of Canada. Issued as Paper No. 108 of the Associate Committee on Grain Research of the National Research Council and Dominion Department of Agriculture.

[2] Inspector, Dominion Seed Branch, Edmonton.

[3] Research Assistant, Associate Committee on Grain Research, University of Alberta, Edmonton.

65% averaged 21% lower. Whitcomb (12) found that, over a four year period, the field germination of oats averaged 15% lower than the most favorable laboratory germination, while the field germination of wheat averaged 20% lower.

Burke (2) studied the germination of wheat, oats and barley under laboratory and field conditions, and found not only a definite difference between laboratory and field results, but also between field results at two stations. The average differences between laboratory and field results were 7.6% and 12.7% for the two stations.

Booth (1), working with oats harvested at various stages of maturity, found the greatest differences between laboratory and field germination with kernels harvested while immature. The average germination of all samples was higher in the laboratory than in the field, but while the laboratory germination was a reliable index of field germination of mature samples, it was unreliable in respect of immature samples.

The effect of frost on germination has also been studied by several investigators. Booth (1) reported that exposure of oats at various stages of maturity to controlled temperatures of from 31° to 27° F., for from one to three hours had no apparent effect on germination. Kiesselbach and Ratcliffe (8) found that injury to seed corn was directly proportional to the moisture content of the kernel at the time of freezing and to the duration of the exposure.

The most extensive studies have been reported by Whitcomb and Sharp (4) and Johnson and Whitcomb (7). Maturity of unfrozen wheat had little effect on germination, but maturity of frozen wheat was very important, the extent of frost injury being directly related to the degree of immaturity. Samples frozen after reaching maturity germinated just as well as unfrozen samples. Germination of frosted wheat was markedly affected by the age of the seed, and the authors conclude that frosted wheat should be tested for germination just before it is to be used as seed.

A possible key to some of the differences between laboratory and field results is offered by the recent work of Whitcomb (13). Oat seeds producing normal plumules in a six day test were capable of producing normal plants in the field, even though the radicles were abnormal or even absent. On the other hand, if the plumules were abnormal, but radicles normal, poor stands could be expected in the field.

Much of the work on germination carried on by botanists and physiologists is undoubtedly related to the present problem. No attempt is made to review or apply the results of such studies since the present study is confined to germination, field survival and yield tests. It seems probable however, that the agreement between laboratory and field germination tests could be improved if the factors contributing to survival of seedlings were more fully understood.

MATERIAL AND METHODS

The samples used in the two preliminary experiments were submitted by farmers in Alberta for the usual germination test. In the first experiment, 10 such frosted samples of the 1928 crop were used, and their behaviour compared with that of high grade sound wheat. In addition to the tests on the bulk samples, tests were also carried out on sound, bran frosted and

frosted immature kernels separated from the bulk material. In the second experiment, 22 frosted samples of the 1930 crop, varying in laboratory germination from 100 to 28%, were submitted to field tests.

The samples used in the main experiments were artificially frozen at the University of Alberta in 1930 and 1932. A complete description of these samples is given by Newton and McCalla (10). The wheat, cut at various stages of maturity, was subjected to temperatures of 28°, 24°, 22° and 18° F. for four-hour periods. An unfrozen control was harvested with each frozen sample. In 1930, Marquis wheat only was frozen, and the samples used in the present study were made up by compositing a number of individual samples as described by Newton and McCalla (10). In 1932, four varieties were used, and the samples reported on in this paper were all individually harvested and frozen.

Laboratory germination tests were made, using the standard blotter method at 18° C. and making counts at 6 and 12 days. These tests were made just prior to the seeding of field plots.

Field germination tests in 1929 were made at Edmonton only; in 1931 at Edmonton, Lacombe Experimental Station and Lethbridge Experimental Station; in 1933 at Edmonton and Lacombe. Duplicate rows of 100 seeds, spaced about two inches apart in the row, were used. Counts were made every second day. The seeds were usually sown directly in a furrow made by a small hand opener. In 1933, at Lacombe, a one-inch pipe was placed in the furrow after it was opened as usual, and one of the assistants walked the full length of the pipe, making the bottom of the furrow smooth and compact. The depth of planting, and physical condition of the seed-bed were, therefore, more uniform than at Edmonton the same year, or than for any of the previous tests.

Yield tests were carried out at the same stations in 1929 and 1931, with plots sown in quadruplicate, three rod rows to each replicate. The rows were one foot apart, and the yield was taken from the centre row only. In 1931 the samples were arranged in order of laboratory germination so that border effect and competition between samples was reduced to a minimum. In all but the first preliminary experiment, the yield plots were seeded at rates adjusted by weight per 1000 kernels and laboratory germination to give equal numbers of germinable seeds per row. The basic rate of seeding the mature unfrozen control was 1.5 bu. per acre.

RESULTS

Preliminary Experiments

The results of the first preliminary experiment are presented in Table 1. Three conclusions of importance in the discussion of later work can be drawn from these results. First, the more severe the frost injury was, the poorer was the wheat for seed purposes. Second, the field germination test gave a reliable indication of the percentage of seeds which could be expected to produce mature plants. Third, the yield from the various classes of seed was to a considerable extent related to the field germination and the percentage of seeds producing mature plants, but not all of the variation could be accounted for by these factors. The nature of the experiment does not justify extended discussion of the results, but the results of the later work show the importance of the conclusions presented.

TABLE 1.—RESULTS WITH FARMERS' SAMPLES OF FROSTED WHEAT, 1928–29

Sample	No. of samples	Germination, %		Seeds producing mature plants %	Comparative yield*	Comparative yield eliminating differences in field germination
		Laboratory	Field			
Control (sound)	5	100	94	92	100	100
Original frosted	10	95	87	83	85	92
Sound kernels from original frosted	6	—	91	88	93	96
Bran frosted kernels from original	9	—	88	84	85	90
Frosted immature kernels from original	6	—	80	77	75	88

* Rates of seeding not adjusted for weight of kernels and laboratory germination.

The results of the second preliminary test are presented in Table 2. These results show that all samples which had a laboratory germination of 90% or higher were relatively satisfactory in field tests. Judging by the results of other investigators, the differences were no greater than might be expected from an average series of samples. The differences between laboratory and field germination of some of the other samples showed much poorer agreement. These results are in agreement with those of other workers, but give little information regarding the cause of the variation in agreement between the two types of test. The lowest yields of even the poorest samples cannot be attributed to frost or other injury to the seed, since some of the yields obtained from the seed with good germination were lower than the lowest yields of the others.

TABLE 2.—RESULTS WITH FARMERS' SAMPLES OF FROSTED WHEAT, 1931–32

No. of samples	Germination, %		Field as % of lab.	Yield,* bu. per acre
	Laboratory	Field		
15	90–100	75–89	81–91	34.5–48.8
2	82	57	70	41
1	65	56	86	43
1	63	53	84	50
1	57	20	35	37
1	45	30	67	38
1	28	22	79	47

* Rates of seeding adjusted for weight of kernels and laboratory germination. Values are mean yields at Edmonton and Lacombe.

The use of commercial samples of unknown origin and treatment is not particularly profitable when the fundamental effects of frost injury are under investigation. It is impossible to determine what factors were important in the injury sustained by the sample which had only 20% germination in the field, but 57% in the laboratory. The two samples with laboratory germination of 65 and 63% and field germination of 56 and 53% respectively, probably contained a fair proportion of sound kernels; but these results cannot be fully interpreted because no information as to stage of maturity, severity or duration of frost exposure is available. The yield results are complicated by the variety factor, which may have

influenced the comparative yields to such an extent that the effects of frost were obscured. The contrast between the completeness and possible interpretation of the results from studies using artificially frozen samples of known history and those from these preliminary experiments shows the advantage of using material of known treatment.

Series of 1930–31

The germination and other pertinent results of the 1930 series are presented in Table 3. The germination results are also presented in Figure 1.

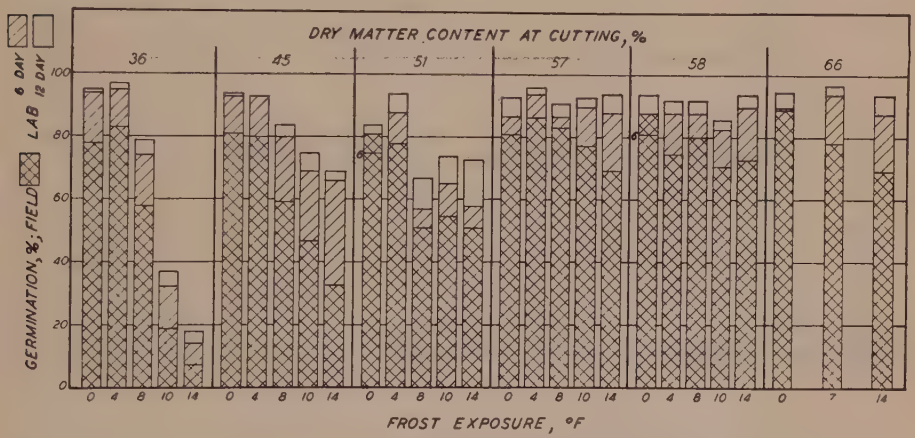

FIGURE 1. Effect of frost exposure at various stages of maturity on the germination of wheat, 1930–31 series.

Laboratory and Field Germination

The high laboratory germination values for all unfrozen controls was for most samples a fair indication of the germination in the field, although there was a slight improvement in field germination with increasing maturity. Four degrees of frost had little effect on either immature or mature wheat, but the more severe exposures reduced the percentage of both laboratory and field germination in samples containing less than 56% dry matter when cut, and field germination in all samples, the reduction being roughly proportional to the maturity of the wheat and the degree of frost exposure. The field results expressed as percentages of the laboratory values show the differences between the germination obtained with the two methods.

It is necessary, of course, to distinguish between germination as determined in the laboratory and emergency of seedlings which constitutes germination in the field. It is probable that two factors contribute to the differences in the results of the two methods. First, it is probable that some of the seeds which produced weak seedlings in the laboratory failed to germinate at all in the field; and second, some of the weaker seedlings produced under field conditions would fail to emerge.

The difference between the field results at the three stations is of particular interest. For the majority of samples the Lethbridge results

TABLE 3.—GERMINATION OF WHEAT EXPOSED TO VARIOUS DEGREES OF FROST AT PROGRESSIVE STAGES OF MATURITY, 1930–31

Sample No.	Dry matter at time of freezing, %	Stage of development	Frost exposure, °F.	Commercial grade	Sound kernels, %	Wt. per 1000 kernels gm.	Germination, %						
							Laboratory		Field				Field as % of laboratory
							6 day	12 day	Lethbridge	Edmonton	Lacombe	Mean	
C 1	35.5	Watery to thin milk	0	Feed	2.0	16.7	94	95	64	82	89	78	82
2	35.2		4	Feed	0.7	17.5	95	97	82	85	84	83	85
3	35.2		8	Feed	0.3	16.6	74	79	50	64	61	58	73
4	36.0		10	Feed	0.6	15.6	32	37	11	20	26	19	51
5	36.0		14	Feed	0.0	15.7	14	18	3	10	9	7	39
C 6	44.8	Thin milk to milk	0	4	32.7	24.8	93	94	77	80	87	81	86
7	45.4		4	5	9.8	25.0	93	93	71	84	85	80	86
8	45.4		8	Feed	3.9	24.8	80	84	44	65	69	59	70
9	44.3		10	Feed	1.9	24.2	69	75	34	54	52	47	61
10	44.3		14	Feed	0.4	23.8	66	69	21	36	40	32	46
C11	50.8*	Milk to early dough	0	5	69.6	27.7	75	84	73	76	95	81	96
12	50.0*		4	6	7.5	27.8	88	94	78	78	79	78	83
13	50.3*		8	Feed	0.7	26.6	57	67	39	61	48	49	73
14	51.9*		10	Feed	0.3	26.6	65	74	42	59	63	55	74
15	51.6*		14	Feed	0.0	28.1	58	73	33	53	62	49	67
C16	56.3	Dough	0	2	96.8	35.1	87	93	62	90	92	81	87
17	57.0		4	4	53.8	36.0	94	96	77	89	95	87	90
18	57.0		8	5	7.8	36.5	87	91	75	88	89	84	92
19	56.7		10	6	5.6	34.7	90	93	72	80	82	78	84
20	56.7		14	6	6.9	35.5	88	94	58	76	77	70	74
C21	57.6*	Dough to firm dough	0	2	86.6	34.1	81	94	81	88	95	88	94
22	55.8*		4	Feed	5.2	32.1	88	92	66	78	82	75	82
23	57.7*		8	6	13.8	34.2	88	92	68	82	91	80	87
24	57.4*		10	Feed	3.6	33.9	83	86	57	72	84	71	83
25	58.2*		14	6	8.4	34.6	90	94	57	79	83	73	78
C26	67.5	Hardening	0	1	97.3	36.6	90	95	83	91	96	90	95
27	65.6		7	5	50.8	37.0	94	97	63	82	90	78	80
28	65.6		14	5	17.7	35.7	88	94	55	69	83	69	73

* Samples from north end of field. Less uniform in development than others.

were definitely lower than those for Edmonton or Lacombe, while in general Lacombe results were the highest. The reason for the difference between Edmonton and Lacombe results is not clear, but the reason for the difference between Edmonton and Lethbridge results is illustrated in Figure 2. Moisture conditions at Edmonton were good from the time of seeding, but at Lethbridge the soil was very dry. At Lethbridge, germination was at first very slow, but following irrigation of the plots 15 days after seeding, there was a sharp increase in the percentage emergence. The poor moisture conditions during the first two weeks, however, reduced the final percentage of seeds producing seedlings capable of emerging. It would be expected that the samples containing the higher proportion of injured seeds would show this reduction to the greatest extent, but such was not the case. It seems likely, therefore, that not only some of the weaker, but also some of the stronger, seeds failed to germinate or emerge.

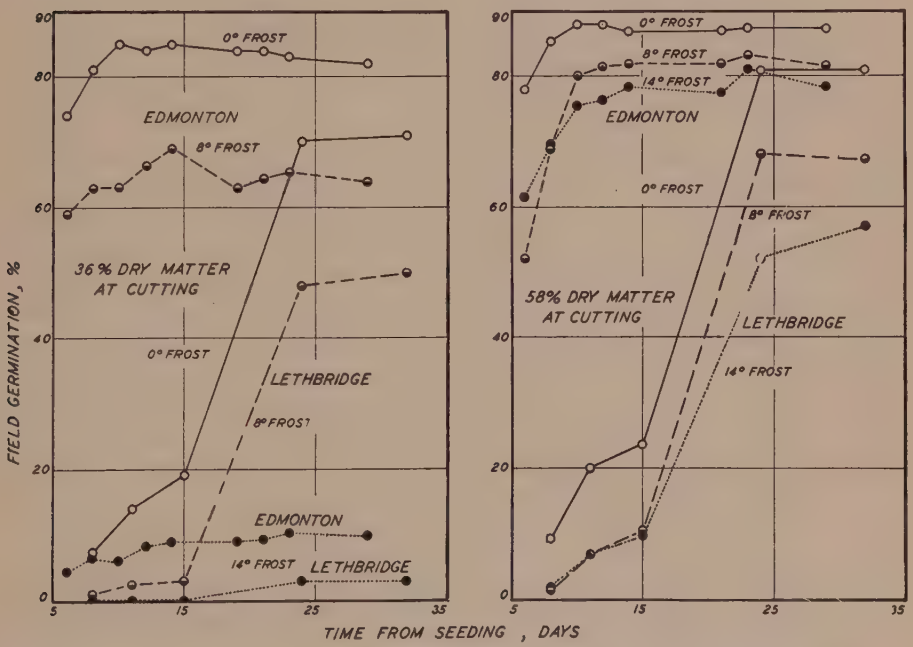

FIGURE 2. Field germination of wheat at Edmonton and Lethbridge, 1930–31 series.

The number of samples in this series is inadequate to show the general relation between commercial grade and seed value. It is obvious, however, that seed value of samples within the same grade may vary enormously in germination and emergence in the field. A more comprehensive appraisal of this problem is possible with the samples of the 1932 series.

Significance of Percentage of Sound and Damaged Kernels

In evaluating seed wheat some attention is paid to the percentage of damaged kernels. With the immature samples of this series it was impossible to estimate the percentage of the kernels injured by frost, because immaturity often obscured the external evidence of frost exposure. From the data published by Newton and McCalla (10), it appears that there was

a greater percentage of frost-injured kernels in the samples harvested at later stages of maturity than in those harvested earlier. The problem is discussed by these authors, with the conclusion that the method of classification was only partially successful.

The percentage of sound kernels can, however, be accurately determined (10), and these values are presented in Table 3. The values obtained are not particularly useful in determining the seed value of the wheat, since one sample with 69.6% sound kernels had practically the same percentage germination in the laboratory and the field as another with 7.5% sound kernels.

The physical classification of kernels may, however, be of some value to the seed analyst, if attention is paid particularly to the green and frozen kernels. In the immature controls most of the immaturity appeared in shrunken rather than green kernels, while at least fairly large percentages of green kernels, or those showing the characteristic wrinkling typical of frost damage, appeared in all samples exposed to severe frosts. The more mature frozen samples have more evidence of frost damage and less of immaturity and greenness.

Significance of Weight per 1000 Kernels

The weights per 1000 kernels are also presented in Table 3. The comparison of weights of the samples within a maturity group leads to the conclusion that this factor is not particularly useful in appraising seed value of frozen wheat. Although the increase in weight of frozen samples was accompanied by higher germination values, the weight per 1000 kernels of unfrozen wheat will vary enormously with conditions such as drought, variety, etc., and caution must be used in interpreting such results in order to estimate frost injury.

Yield

Rates of seeding the yield plots, and the yields obtained from this series of seed are presented in Table 4.

TABLE 4.—RATES OF SEEDING ADJUSTED FOR WEIGHT PER 1,000 KERNELS AND LABORATORY GERMINATION, AND YIELD, 1930–31 SERIES

Average dry matter at freezing, %	Frost exposure					
	0	4	8	10	14	Mean
Rate of seeding, bu. per acre.						
35.2 – 36.0	0.69	0.72	0.94	2.57	5.16	—
44.3 – 45.4	1.02	1.03	1.18	1.58	1.85	—
50.0 – 51.9	1.08	1.19	1.22	1.48	1.48	—
56.3 – 57.0	1.50	1.50	1.50	1.53	1.76	—
55.8 – 58.2	1.41	1.35	1.44	1.55	1.57	—
65.6 – 67.5	1.50	—	1.50	—	1.79	—
Yield, bu. per acre. (Average Edmonton and Lacombe)*						
35.2 – 36.0	44.8	51.1	45.8	48.8	43.2	46.7
44.3 – 45.4	46.6	50.5	49.6	47.2	47.2	48.2
50.0 – 51.9	53.0	50.0	41.5	44.6	47.8	47.4
56.3 – 57.0	54.1	48.5	49.1	53.5	45.1	50.6
55.8 – 58.2	52.6	52.5	48.3	47.6	52.7	50.7
65.6 – 67.5	55.5	—	52.4	—	49.1	52.3
Mean yield	51.1	50.5	47.8	48.3	47.5	—

* Lethbridge results omitted because samples damaged by birds.

The adjusted rates of seeding are of interest because it has been claimed by farmers that no increase in the rate of seediug immature or frozen wheat is necessary since the larger number of smaller kernels will compensate for the poorer germination. For most of the samples in the present series, this appears to be true. Since the more immature, severely frozen samples were injured to a greater extent than any wheat likely to be used for seed purposes, only a few of the rates used varied appreciably from the basic rate of 1.5 bushels per acre.

The adjustment in rate of seeding was made on the basis of laboratory germination. Had emergence tests been used, the rates of seeding the immature frozen samples would have been even higher than they were.

The yield trials are inconclusive, for although there was a tendency for yield to be higher for unfrozen than for frozen, and for mature than for immature samples, an analysis of variance shows that these differences were not significant. It is almost certain that the yields of some of the immature heavily frozen samples would have been significantly lower had the rates of seeding not been increased. On the other hand, the yields of the most immature controls and lightly frozen samples were not significantly reduced by rates of seeding less than half normal in terms of bushels (but not number of seeds) per acre.

The uniformity in yield results is the more remarkable since there were distinct differences in the stand and vigor of the seedlings in the yield plots three weeks after seeding. All of the plots sown with heavily frosted seed produced seedlings lacking in vigor, this effect being definite, even in the sample which had reached a dry matter content of 65.6% at the time of freezing. Once the seedlings were established, however, the differences among plots gradually decreased, until at maturity most of those which had originally appeared very poor were indistinguishable from the controls.

While few or no data of a like nature have been found in the literature, similar results were obtained by Fryer with oats (3). Considerable work has been carried out on the effect of rates of seeding on yield. Hutchison (4) presents four-year results with wheat seeded at from 33 to 129 pounds per acre. The lighter rates resulted in more heads per plant, and more grain per head, than did the heavier rates. At rates from 61 to 129 pounds the yields were fairly uniform. Rates lower than 96 pounds per acre were not sufficient to control weeds on infested land.

In the present experiment, conditions of germination and growth were both good. It seems probable that the weak seedlings mentioned above might not have developed as well under adverse conditions or in competition with weeds. Under the conditions of the experiment, however, good yields were obtained, and it is likely that the basic rate of seeding was higher than necessary.

Series of 1932-33

The 1932–33 series covered a range of values for dry matter at time of cutting from 46.2 to 89.3%, with a large proportion of the samples harvested and exposed to frost at later stages than were any of the 1930 samples. Individual germination results in Table 5 are presented only for those samples commercially degraded to 4 Northern or lower. The

field counts for individual Reward samples, unfrozen and exposed to 10° of frost at four stages of development are presented in Figure 3. All of the germination results averaged according to commercial grade are presented in Table 6.

TABLE 5.—GERMINATION OF WHEAT WHICH WAS SEVERELY COMMERCIALLY DEGRADED BY FROST EXPOSURE, 1932–33

Variety	Dry matter when cut, %	Frost exposure, °F.	Commercial grade		Germination of frozen samples, %		
			Of unfrozen check	Of frozen samples	Laboratory 12 day	Field*	Field as % of laboratory
Reward	46.2	10	4 Nor.	Feed	92	39	42
Reward	50.7	10	3 Nor.	Feed	98	65	66
Garnet	51.1	10	3 Nor.	Feed	65	39	60
Marquis	57.2	10	2 Nor.	Feed	100	84	84
Marquis	60.5	10	1 Nor.	Feed	100	86	86
Marquis	62.8	10	1 Nor.	Feed	100	93	93
Red Bobs	55.0	10	1 Hard	6	99	76	77
Red Bobs	55.4	10	1 Hard	6	99	88	89
Marquis	76.5	10	1 Hard	6	100	93	93
Garnet	56.2	10	3 Nor.	5	99	79	80
Reward	57.6	10	2 Nor.	5	99	90	91
Reward	58.2	10	1 Hard	5	100	89	89
Red Bobs	59.6	10	1 Nor.	5	97	94	97
Marquis	78.4	10	1 Hard	5	100	96	96
Reward	46.2	0	4 Nor.	4 Nor.	100	92	92
Marquis	57.2	4	2 Nor.	4 Nor.	100	91	91
Reward	62.7	10	1 Nor.	4 Nor.	99	93	94

* Mean of Edmonton and Lacombe.

TABLE 6.—MEAN RELATION BETWEEN COMMERCIAL GRADE AND GERMINATION, 1932 SERIES

No. of samples	Dry matter at time of freezing %	Frost exposure °F.	Commercial grade	Germination, %		
				Laboratory 12 day	Field	Field as % of laboratory
6	46.2–62.8	10	Feed	65–100	39–93	42–93
3	55.0–76.5	10	6	99–100	76–93	77–93
5	55.2–62.7	10	5	99–100	79–96	80–97
1	46.2	0	4 Nor.	100	92	92
1	57.2	4	4 Nor.	100	91	91
1	62.7	10	4 Nor.	99	93	94
3	50.7–56.2	0	3 Nor.	100	90–93	90–93
4	50.7–62.7	4	3 Nor.	100	90–94	90–94
3	62.4–70.9	10	3 Nor.	97– 99	91–93	94–96
4	57.2–70.9	0	2 Nor.	99–100	87–94	87–94
7	55.4–70.9	4	2 Nor.	98–100	88–94	90–94
3	78.5–81.9	10	2 Nor.	99–100	89–95	90–95
6	59.6–80.5	0	1 Nor.	98–100	90–95	92–97
3	55.0–80.5	4	1 Nor.	100	91–94	91–94
3	68.8–89.3	10	1 Nor.	99–100	94–95	94–95
14	55.0–89.3	0	1 Hard	98–100	91–96	91–97
11	62.4–89.3	4	1 Hard	99–100	91–95	91–95
3	78.5–86.8	10	1 Hard	97–100	93–95	93–96

The injurious effect of frost, and the gradual decrease of this effect with increasing maturity is well illustrated in Figure 3. From the time the wheat reached 58% dry matter, 10° frost had little effect on subsequent field germination. This result agrees only fairly well with those obtained with the 1930 series, since the most mature frosted samples (65.6% D.M.) were reduced in field germination. This result, however, agrees with the conclusions of Newton and McCalla (10) regarding the effect of frost on the chemical composition and quality of the wheat.

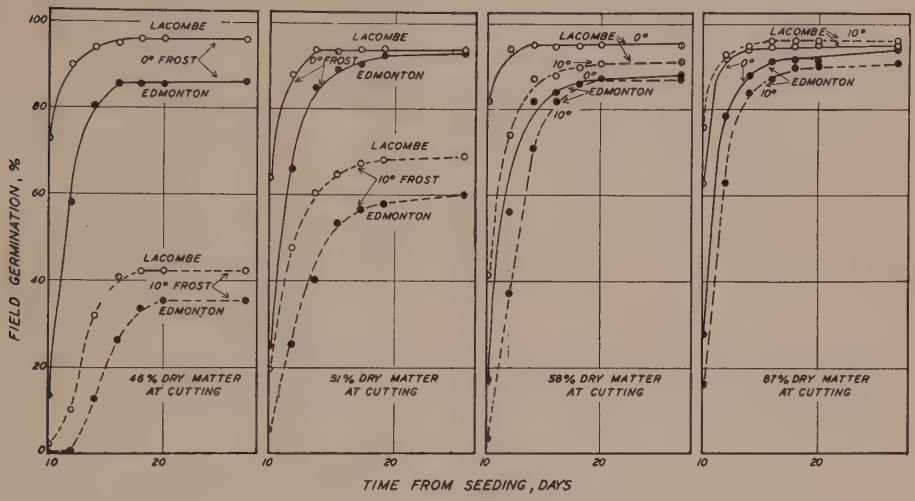

FIGURE 3. Field germination of wheat at Lacombe and Edmonton, 1932–33 series.

The difference between the field results obtained at Edmonton and Lacombe are believed to be the result of the different method of preparing the seed bed, since conditions for germination at both places were otherwise similar and good. The uniform, packed seed bed already described, resulted in not only a more rapid, but also a higher, germination of both unfrozen and frozen samples. These effects persisted even for the most mature seed. The explanation is probably the same as that offered to account for the differences between the Edmonton and Lethbridge results with the 1930 series, except that in that case the loss of weaker seedlings at Lethbridge was due to poor moisture conditions, while in the present case the loss at Edmonton was due to poorer physical condition of the seedbed.

The results presented in Tables 5 and 6 show the range of injury which occurred to samples within the individual commercial grades. It may be concluded from these results that the laboratory germination may be taken as a satisfactory index of probable emergence in the field for all samples of seed grading 4 Northern or better. In this respect a knowledge of the commercial grade should be of value to the seed grader. When wheat grades lower than 4 Northern, attention should be paid to all factors which might aid in fairly grading that wheat for seed purposes, because it is obvious that some samples which are commercially graded Feed may make satisfactory seed, while other samples with the same commercial grade should be rejected.

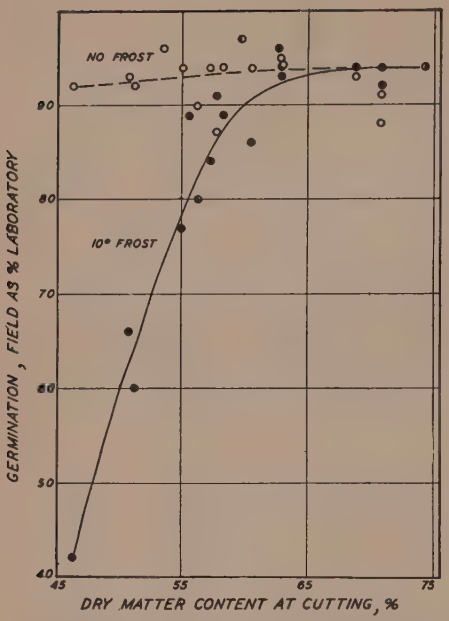

FIGURE 4. Field, as a percentage of laboratory germination, and the influence of stage of maturity and frost exposure, 1932–33 series.

Laboratory germination of immature samples of this series was no more a reliable index of actual field emergence than it was for the 1930 series. Only one of the samples had a laboratory germination below 92%, but the relation between laboratory and field germination, illustrated in Figure 4, shows that all immature frosted samples failed to germinate in the field as well as expected from the laboratory results. The controls, however, gave uniform results regardless of maturity.

APPLICATION OF RESULTS

The laboratory germination results presented in this paper were all obtained by the standard blotter methods, criticisms of which method have already been mentioned in the literature review. The methods now in use in the laboratories of the Seed Branch overcome, to some extent at least, the faults found in this study. All poorer grade wheat samples are now tested in sand in order to eliminate the weaker type seedlings which would be counted in the blotter test.

It seems likely that Whitcomb's findings (13) regarding the interpretation of laboratory results have a direct application here. If a normal plumule is essential for seedling survival, then some seedlings which might have been counted in the blotter test will not emerge in the sand culture.

The use of weight per 1000 kernels, and percentage frosted or otherwise injured kernels, in appraising seed value is justifiable only when adequate consideration is paid to the factors other than frost which may have had a part in determining the result obtained. Wheat grown under conditions of ample moisture supply may have a higher weight per 1000 kernels at a definitely immature stage, than a mature sample of the same variety grown under drought conditions. Immaturity in itself is apparently not a serious factor affecting seed value, but to distinguish between immaturity and frost damage is often difficult. The percentage of kernels with a definite green color may give some hint of frost injury where the external evidences of frost are otherwise obscured by the evidences of immaturity.

The yield trials show that even very immature and relatively heavily frosted seed may be quite satisfactory under conditions such as obtained in the present study. Conditions were, however, very favorable, and the poorer seedlings which were originally weak and spindly might have had little chance if grown under less favorable circumstances. Loss on weed

infested land would probably have been much greater (4), while it has also been shown (9) that such seedlings are more susceptible to attack from parasitic fungi. The results here presented refer to spring wheat only, and it seems probable that they would not be applicable to winter wheat, since it has been shown (11) that any type of injury such as weathering, sprouting or even severe mechanical injury resulted in a significant decrease in winter hardiness of the seedlings.

CONCLUSIONS

The results of these studies in general confirm those of other workers in that:

(a) Immaturity by itself is apparently not a serious factor in reducing seed value of wheat;

(b) Frost exposure of over 4° F. reduced the percentage of seeds which will germinate in direct proportion to the severity of the frost.

(c) The laboratory germination determined by the standard blotter test is a satisfactory index of the field germination of unfrozen and mature frozen wheat, but not of immature frozen wheat.

The results further show:

(a) That commercial samples graded below 4 Northern should be carefully examined for degree of immaturity and frost exhibited, because the range of maturity within these grades varies widely, and the effect of frost decreases proportionately with increasing maturity. All samples commercially graded 4 Northern or higher were satisfactory for seed;

(b) That the yields obtained even from seed with poor laboratory and field germination were satisfactory when the seed was sown on clean land under good conditions of growth. The possible failure of such seed under adverse conditions is suggested.

ACKNOWLEDGMENTS

The writers wish to express their indebtedness to Mr. G. M. Stewart and Mr. C. T. Tapp, of the Seed Branch laboratory at Calgary; and to other members of the various organizations whose co-operation made this study possible.

REFERENCES

1. Booth, E. G. Minnesota Agr. Exp. Sta. Tech. Bul. 62. 1929.
2. Burke, T. W. L. Dominion Dept. Agr. Seed Branch Memorandum. December, 1931.
3. Fryer, J. R. Unpublished results.
4. Hutchison, R. E. J. Am. Soc. Agron. 28 : 699-703. 1936.
5. International Seed Testing Congress, Rome. 1928.
6. International Seed Testing Congress, Wageningen. 1931.
7. Johnson, A. H. and Whitcomb, W. O. Montana Agr. Exp. Sta. Bul. 204. 1927.
8. Kiesselbach, T. A. and Ratcliffe, J. A. Nebraska Agr. Exp. Sta. Res. Bul. 16. 1920.
9. Mead, H. W. Proc. World's Grain Exhibition and Conference, Regina, 2 : 278-282. 1933.
10. Newton, R. and McCalla, A. G. Can. J. Res. 10 : 414-429. 1934; C, 13 : 1-31, 263-282. 1935.

11. Suneson, C. A. and Peltier, G. L. J. Am. Soc. Agron. 28 : 687-693. 1936.

12. Whitcomb, W. O. Proc. Assoc. Off. Seed Anal. North America 16th Ann. Meeting, pp. 60-62. 1924.

13. Whitcomb, W. O. Proc. Assoc. Off. Seed Anal. North America 27th Ann. Meeting. 1935.

14. Whitcomb, W. O. and Sharp, P. F. J. Agr. Res. 31 : 1179-1188. 1925.

15. Wright, W. H. Proc. Assoc. Off. Seed Anal. North America, 13th Ann. Meeting. 1921.

Résumé

La valeur de la semence de blé gelé. N. G. Lewis et A. G. McCalla.

Les résultats de ces études confirment en général ceux qui ont été obtenus par d'autres chercheurs, en ce qui concerne les points suivants: (a) La semence de blé n'est pas affaiblie d'une manière sérieuse par l'immaturité; (b) Une exposition à une gelée de plus de 4° F. a réduit le pourcentage des semences aptes à germer, en proportion directe de la sévérité de la gelée; (c) La faculté germinative déterminée au laboratoire, par l'essai au papier buvard, est un indice satisfaisant de la faculté germinative dans le champ, du blé non gelé et du blé gelé mûr, mais pas du blé gelé vert. Les résultats obtenus indiquent encore: (a) que les échantillons commerciaux classés dans une catégorie inférieure à celle de 4 Nord devraient être soigneusement examinés pour le degré d'immaturité et de gelée qu'ils présentent, parce que l'échelle de maturité varie beaucoup dans ces catégories et que l'effet de la gelée diminue proportionnellement avec l'avancement de la maturité; tous les échantillons classés commercialement 4 Nord ou mieux étaient satisfaisants pour les semailles; (b) que le rendement obtenu même avec la semence à pauvre faculté germinative, au laboratoire et dans le champ, était satisfaisant lorsque cette semence était semée sur une terre propre, dans de bonnes conditions de végétation. Il est possible cependant que cette semence ne réussisse pas à germer dans des conditions défavorables.

TYPES OF PEACH BUDS IN RELATION TO NURSERY PRACTICE

W. H. Upshall[1]

Ontario Horticultural Experiment Station, Vineland, Ontario

[Received for publication November 20, 1936]

Most nurserymen prefer to use peach bud sticks obtained from their own nursery rows rather than from bearing trees. They contend that they cannot get as good results in stand or growth when they are forced to use buds from the latter source; and yet there are times when they have no choice in the matter and must of necessity get buds from bearing trees. This is the case when commencing to propagate a new variety and in getting a fresh start with an old variety which is suspected to be partially or wholly untrue-to-name in the nursery row.

Among nurserymen there is a very prevalent notion that double and triple peach buds are to be avoided "because they are fruit buds and will result in a poor stand and poor growth." The bud most desired is a single one. Some nurserymen do not realize that single fruit buds occur on the peach and that there is, therefore, a real danger in the deliberate selection of single buds. Some varieties have many single fruit buds; others have very few. If single fruit buds and single blossom buds could readily be differentiated by eye at budding time the latter could be discarded, but such is not the case. Classification in this way is a very uncertain undertaking and particularly at the commencement of the peach budding season when all buds are relatively small. On the other hand one can depend with near certainty on the presence of a leaf bud at a node where there are double or triple buds.

Explanation. The main petiole, the "handle" useful in the budding operation, was removed in order that the bud arrangement could be shown

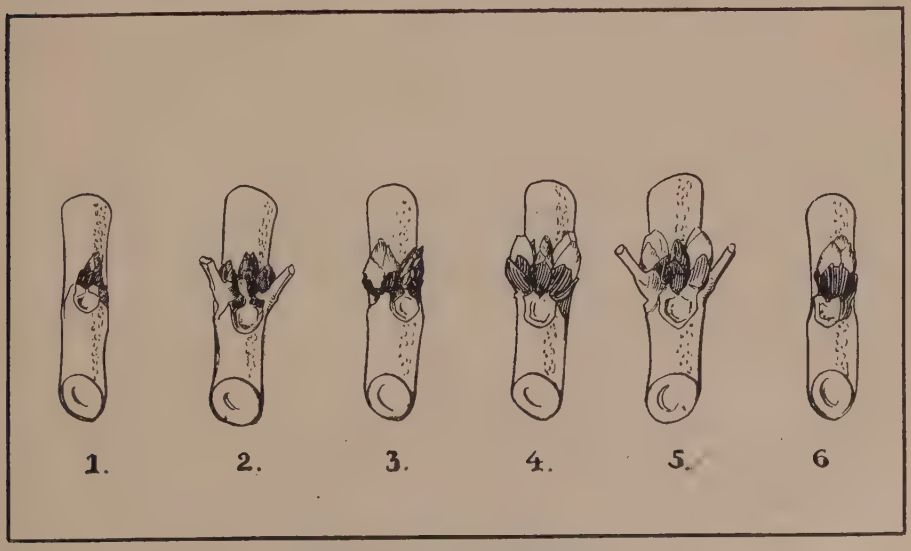

Figure 1. Types of peach buds

[1] Research Specialist.

clearly. Leaf buds are marked by heavier shading than blossom buds. (For this drawing the writer is indebted to Miss L. Heringa of the Department of Horticulture, Ontario Agricultural College.)

1. Single leaf bud.
2. Three leaf buds—occur only on very strong growing shoots.
3. A blossom bud at the left and leaf bud in the central position. A blossom bud may occur at either side of the leaf bud.
4. A blossom bud at each side and leaf bud in the centre. At this node there was one leaf only.
5. A blossom bud at each side and leaf bud in the centre. At this node there was a large main leaf and two smaller side leaves.
6. Single fruit bud—to be avoided in the budding operation. Compare size and plumpness with the single leaf bud (No. 1).

Bud type number 2 should be used only when better buds are scarce as on account of its size and construction it is difficult to place in stock of average size. Furthermore it often results in the starting of a two or three stemmed tree, the pruning of which to a single trunk gives a certain setback to the tree. At the time of trimming the leaves from the budsticks it may be desirable to cut the side petioles close to the buds in types 2 and 5 else they may be a hindrance in the tying operation.

TABLE I.—RESULTS FROM BUDDING SINGLE AND DOUBLE OR TRIPLE PEACH BUDS TAKEN FROM BEARING TREES; 50–140 BUDS OF EACH TYPE WERE BUDDED EACH YEAR

Year	Variety	Per cent of buds growing the following season	
		Single buds	Double or triple buds
1931	Valiant	55	90
1932	Veteran	60	87
1934	Elberta	51	52

NOTE.—In 1933 no budding stocks were available.

An analysis of Table I shows that *there was a distinct gain in stand of buds as a result of using double or triple buds in preference to single buds*. Undoubtedly some of the single buds were fruit buds and therefore useless in the development of a shoot but it is also quite possible that, on the whole, the single buds are not as strong as the double or triple ones.

During the course of these experiments there has been no visual evidence to substantiate the contention of some nurserymen that growth of tree is depressed by the presence of one or two fruit buds. In 1931 a few peach fruits actually set on the newly placed buds. Some of them grew as large as a walnut before dropping off but in the other two seasons the blossom buds abscissed before or just after blossoming.

On the basis of these observations our main recommendation to nurserymen is—do *not* use large plump single buds from bearing peach trees.

Résumé

Pratiques de pépinières recommandées pour les différents types de boutons de pêcher. W. H. Upshall, Station expérimentale d'horticulture, Vineland Station, Ont.

On trouve généralement de un à trois boutons dans les aisselles des feuilles de pêcher. Il est essentiel pour la greffe en écusson que l'un des boutons au nœud soit un bouton de feuille, sinon il ne se développe pas de tige. Comme les boutons de fleurs sur le pêcher sont simples, on fera bien de rejeter tous les gros boutons simples. Les boutons doubles ou triples, qui comprennent presque toujours un bouton de feuille, sont très satisfaisants pour fins de propagation.

THE NORTHERN LIMITS FOR POTATO BEETLE INFESTATION

E. H. Strickland[1]

University of Alberta, Edmonton, Alta.

[Received for publication September 25, 1936]

The rather sudden appearance of potato beetles *(Leptinotarsa decemlineata)* over the greater part of Northern Alberta which is well settled has caused much alarm to potato growers. Many fear that they may be faced with the permanent problem of applying control measures.

Earlier records of the distribution of this insect in Alberta, however, indicate that there is little likelihood of this being the case. The potato beetle is permanently established in the southern half of the province where it was first observed in 1899 (1). Here it has caused losses for at least 25 years, but it is not often encountered in destructive numbers much to the north of Calgary and it is rarely seen at all within one hundred miles of Edmonton. The only previous records are those of 1923, and again in 1928, when specimens were found in small numbers in a few gardens in Edmonton. In each instance they had disappeared entirely by the following year. From the latter date until 1936 no one reported seeing them anywhere within a hundred miles to the south. This year, however, they reappeared in scattering abundance throughout the entire intervening territory and they have penetrated as far north as to Goodfish Lake, which is fify miles to the north of Edmonton. In so far as is known they have never invaded the Peace River District.

The chief limiting factor in the northward spread of this beetle appears to be that of success in hibernation. Its favoured food plant, the potato, is now grown, even if somewhat sporadically beyond the Athabasca River, to as far north as the Arctic Ocean. It may be questioned whether the potatoes grown at the Catholic Mission at Aklavik offer an entirely satisfactory solution to the problem of producing a vegetable diet for human consumption in the Arctic, but it must be admitted that they are undoubtedly potatoes. At all events, potatoes are grown annually in large numbers many miles to the north of the territory which has been invaded by the potato beetle. The northern limits of its geographical range fluctuate considerably from year to year and appear to be limited by two significant factors. These are the humidity of the soil in late autumn and the actual low temperatures to which the hibernating beetles will be subjected during the winter.

Mail and Salt (2) have shown that the depth at which the beetles hibernate varies considerably with the texture of the soil into which they have to burrow in order to do so. The average depth in Alberta would appear to be about 18 inches of actual burrowing even though we have a record of an adult which had simply crawled under a stone on the ground surface at Medicine Hat. The late Mr. F. S. Carr stated that this beetle was alive in February, when it was found.

[1] Professor of Entomology.

Although the writers just quoted found that, under laboratory conditions, there was a considerable variation in the cold resistance of individual beetles, there is little information available regarding the low temperatures at which they succumb in the field. It would appear that this varies considerably, and that this variation may be due in part to the amount of moisture in the soil in which they are hibernating. How, otherwise, can one explain the somewhat paraxodical fact that the majority of beetles hibernate successfully in Southern Alberta, where normally there is so little snow that frost penetrates more deeply into the soil than it does further north, where less severe soil temperatures are almost always fatal to them?

In the case of many winter-hardy insects it has been shown that one essential to cold resistance is the removal from their bodies, prior to their subjection to sub-freezing temperatures, of all surplus water in order that all of the small amount which must be retained to preserve life can be finely divided as a colloid "emulsion", which is capable of withstanding temperatures well below freezing without actual crystallization. Payne (3) has shown that the larvae of Japanese beetles can hibernate successfully at much lower temperatures in dry soil than they can in moist, because in the former they can get rid of their surplus water whereas this is not possible in the latter. The same principle would appear to apply to the potato beetle adult. In northern Alberta, soil moistures are usually high in the fall and early winter; in the south this is less frequently the case, and it would appear that the southern beetles are normally able to withstand lower actual soil temperatures than are those which attempt to hibernate further north.

Several writers have drawn attention to the fact that a good covering of snow, in northern latitudes, has a pronounced effect on the ability of the beetles to hibernate satisfactorily, but this obviously fails to explain entirely the distribution of the potato beetle in Alberta, since it hibernates best where there is the least snow and the greatest consequent frost penetration.

In this connection it is of interest to note that, in the neighbourhood of Edmonton, frost penetration has been about two feet or more for a number of years up to and including the winter of 1933–34. It is, however, on record that in 1927, the year preceding an earlier appearance of the beetle in the district, early falls of snow reduced frost penetration to a few inches only. In 1934–35 early falls of snow prevented soil freezing throughout the winter until February, when an exceptionally mild spell removed nearly all of the winter's accumulation of snow. A recurrence of cold weather in March froze the soil to a varying depth. In a few places, where this was measured, it was about one foot deep. It is probably, in the light of subsequent events, that a few beetles which, earlier in the year, had migrated into the district from farther south managed to survive this winter, though in insufficient numbers for their progeny to attract enough attention for comment in 1935.*

The winter of 1935–36 was even more abnormal. In the first place the soil was drier than usual in the autumn. Heavy falls of snow blanketted

* Since this was written we have been told that a few beetles were seen, in 1935, at St. Albert, about eight miles north of Edmonton.

the entire country in October and, even though the winter was unusually severe, the ground was never frozen. As a result conditions were ideal for the survival of hibernating beetles. In early summer larvae were so abundant that they attracted widespread attention and they caused appreciable damage Adults were fairly numerous at the end of the season and the soil was drier than it had been for a number of years. A recurrence of heavy snow preceding the low temperatures of winter may result in an unprecedented outbreak of potato beetles in northern Alberta in 1937. It is, however, more likely that the winter will approach the normal for this part of the province and that the beetle will once more be restricted to its usual range.

The only reference we have been able to locate with regard to the known distance that beetles migrate by flight during a season is one by Fernald to the effect that, in the early years of its dispersal across America, it averaged about fifty miles a year. It would appear that, with favourable winds, the beetles must be capable of traversing upwards of one hundred miles in a year. Otherwise, it is difficult to account for its repeated appearance in districts which are at about this distance from its known range immediately after a winter which has been unusually satisfactory for hibernation.

One possible sidelight on the distribution of potato beetles in Alberta may not be out of place here, and it is given for what it may be worth. Several years ago a farmer near Medicine Hat sent me, in the spring, eight living potato beetles. He stated that he had observed one coming out of a gopher burrow, and soon afterwards he saw another. Being a man of an enquiring mind, he obtained a spade and dug to the bottom of the burrow, which, if I remember rightly (I do not still possess his letter) he estimated to be about two feet deep. He continued to dig! At a distance of about eighteen inches below the bottom of the burrow he found the eight beetles which he sent me. They were still "hibernating" in the soil. It may be a coincidence that the permanent range of the potato beetle in Alberta approximates that of gophers in the greatest abundance. Their burrows certainly should offer a beetle a good start in its quest for a means of descent below the danger line for hibernation.

A final point in connection with the present northern spread of the beetle arises from a sample of larvae, collected locally, which were submitted to the University for identification in July. The larvae were identified and set to one side in their box, which contained, in addition, a quantity of potato leaves. In September the box was reopened and was found to contain six adults (which had matured in captivity), one pupa, three larvae, and twenty-two larvae containing Tachinid puparia from which sixteen adult *Doryphoraphaga (Phorocera) doryphorae* had emerged. This Tachinid is nowhere recorded as an abundant parasite of potato beetles, yet in this instance nearly 70% of the larvae were parasitized. It was then too late to make a study of its prevalence here. We have no records of capturing the adults in former years in our general collecting and one specimen only was taken during the current summer. It would appear, however, from its heavy parasitism of these potato beetle larvae during the first year that the latter have been sufficiently abundant to

attract attention anywhere nearer than one hundred and fifty miles to the south, that it is capable of breeding in some host other than the potato beetle when the latter is not present in this area.

REFERENCES

1. Gibson et al. Dom. of Canada. Dept. of Agric. Bull. 52. 1925.
2. Mail and Salt. Journ. Econ. Ent. Vol. 26. 1933.
3. Payne. Biol. Bull. Vol. 52. 1927.

Résumé

Les limites septentrionales de l'invasion du doryphore (bête à patates). E. H. Strickland, Université de l'Alberta, Edmonton, Alta.

La bête à patates fait parfois son apparition sur la plus grande partie du nord de l'Alberta, mais il est rare qu'elle soit assez nombreuse pour causer des dégâts importants au nord de Calgary. Le principal facteur qui s'oppose à la propagation de cet insecte vers le nord paraît être l'hibernation. La plante dont le doryphore se nourrit se rencontre dans le nord jusqu'à l'océan Arctique, mais l'hibernation de l'insecte' dans les conditions climatériques paraît être déterminée par sa résistance au froid de l'Alberta, et cette résistance dépend à son tour de la facilité avec laquelle l'insecte peut se débarrasser avant l'arrivée des froids du surplus d'eau que renferme son corps. Cette réduction de l'eau peut se faire plus facilement dans la partie sud et plus sèche de la province que dans la partie du nord, où la terre est plus humide et où l'hiver fait son apparition plus tôt. C'est pourquoi, en une année ordinaire, la protection fournie par la couche plus épaisse de neige dans la partie nord de la province est contrebalancée par une moins grande résistance au froid, à cause de la difficulté qu'éprouve l'insecte de réduire la teneur en eau du corps avant les gelées. Il y a certaines combinaisons de température qui favorisent la réapparition de l'insecte dans le nord de l'Alberta, telles sont les chutes précoces de neige qui protègent la terre contre la gelée et les longs vols effectués lorsque les circonstances sont favorables. Cependant, les conditions de sol et de climat et la présence locale du parasite du doryphore, *Doryphorophaga*, s'opposent en général à ce que cet insecte fasse plus que de rares apparitions dans la région qui s'étend jusqu'à une centaine de milles au sud d'Edmonton.

LINKAGE TESTS WITH THE YELLOW-HEAD AND DOMINANT-WHITE PLUMAGE AND WHITE-SKIN CHARACTERISTICS IN DOMESTIC FOWL[1]

ALAN DEAKIN AND GEORGE ROBERTSON[2]

Central Experimental Farm, Ottawa, Canada

[Received for publication January 28, 1937]

The yellow pigmented head characteristic, which includes the comb, wattles, ear-lobes and face, appeared as a mutation to the usual red-headed condition in two pullets of the Farm flock. Since that time several other mutants have appeared in the regular breeding flock. Breeding tests showed yellow-head to be a simple autosomal recessive to red-head (Deakin and Robertson[3]) and was assigned the symbols "gg". It was further pointed out that at sexual maturity the yellow pigment begins to disappear from the head furnishings with the result that males become scarcely distinguishable from normal red heads, but that females retain a pale coloured head. It was deduced, therefore, that the yellow-head factors have an effect upon the vascularization of head furnishings, especially those of the females. The yellow-head characteristic was considered to be dependent upon the presence of yellow pigment in the skin, and thus the factors involved were either recessive extension factors, or normal birds have dominant factors which inhibit the extension of the yellow skin pigment into the head furnishings.

To test experimentally the above deductions, Barred Plymouth Rocks with yellow heads (ggww) were crossed with red-head, white skinned birds (GGWW) of Light Sussex extraction, and the F_1 reciprocally back-crossed to yellow-head birds. This cross is also a linkage test for the white skin and yellow-head factors. The results are given in Table 1, the segregants being classified according to sex and cross as well as skin and head colour. The number of segregants is not large, owing to poor production during the breeding season and poor hatchability.

It can be noted that of the 61 segregants, only 15 have yellow heads, thus indicating that the yellow-skin factor is necessary for the expression of the yellow-head characteristic. Further, no linkage of the yellow-head and white-skin factors is evident since there are 15 yellow heads and 16 red heads classified under yellow skin. If linkage were evident, the red-head group would be in the minority, corresponding with the degree of linkage.

With regard to the segregants classified under white skin, 24 have red heads and only six pale heads, whereas the numbers in each group should be approximately the same if, as postulated, the yellow-head factors affect the vascularization of head furnishings. However, there is the problem of distinguishing the pale heads from red heads. It is quite possible that the trait could be more easily and accurately recognized at a particular age period. Our ranging facilities for young stock do not lend themselves to frequent examinations of the growing birds. It is felt, therefore, that the yellow-head factors affect the vascularization of the head furnishings, but that the accurate recognition of the trait presents difficulties.

[1] Contribution from the Division of Poultry Husbandry.
[2] Geneticist, and Assistant Dominion Poultry Husbandman, respectively.
[3] American Naturalist, 59 : 378. 1935.

A linkage test involving yellow-head and dominant-white plumage factors was also made. A yellow-head Barred Rock male (ggii) was mated with single comb White Leghorn females (GGII) and the F_1 backcrossed to a yellow-head Barred Rock male. The results are given in Table 2, the segregants being classified according to sex, plumage and head colour. The heterozygous whites are usually a little flecked, while the coloured birds have the barred or cuckoo pattern. The numbers are very small, involving a total of only 34 birds, but the distribution is such that no linkage is evident between yellow-head and dominant-white plumage factors. The yellow pigmentation of the head furnishings in birds with white plumage is not so intense as in those with coloured plumage.

SUMMARY

No linkage is evident between the yellow-head and dominant-white plumage factors nor between yellow-head and white-skin factors.

The yellow-head factors cause an extension of the yellow-skin pigment into the head furnishings, the yellow-head characteristic thus being dependent upon the presence of yellow pigment in the skin.

The evidence indicates that the yellow-head factors affect the vascularization of head furnishings, causing pale-coloured heads.

TABLE 1.—CLASSIFICATION OF PARENTS AND BACKCROSS SEGREGANTS FOR HEAD AND SKIN COLOUR

Parents		Backcross progeny				
			Yellow skin		White skin	
♂♂	♀♀	Sex	Yellow head	Red head	Red head	Pale head
Yellow head and skin	Red head, white skin		gw	Gw	GW	g?W
ggww	GgWw	♂♂	2	2	3	—
		♀♀	4	5	4	1
Reciprocal cross		♂♂	3	4	12	3
GgWw | ggww		♀♀	6	5	5	2
Totals			15	16	24	6

TABLE 2.—CLASSIFICATION OF PARENTS AND BACKCROSS SEGREGANTS FOR HEAD AND PLUMAGE COLOUR

Parents		Backcross progeny				
			Coloured		White	
♂	♀♀	Sex	Yellow head	Red head	Yellow head	Red head
Barred; Yellow head	White; Red head		gi	Gi	gI	GI
ggii	GgIi	♂♂	3	2	5	4
		♀♀	4	5	4	7
Totals			7	7	9	11

PROTEIN LEVELS IN THE FATTENING RATION AS INFLUENCING THE COMPOSITION OF THE THIGH MUSCLE WITH DIFFERENT AGES OF POULTRY MEAT STOCK[1]

W. A. Maw[2], A. J. G. Maw[3], R. Holcomb[4], and L. H. Bemont[5]

Macdonald College, Que.

[Received for publication January 27, 1937]

The feeding under confinement for meat quality in poultry carcasses during the growth period entails the maintenance of growth as well as the production of maximum fat to give finish to the carcass. A measure of finish or quality in the carcass is the amount of fat laid down internally in the muscle and in the abdominal cavity, as well as that externally attached to the muscle or the skin and in the skin. There is relatively little evidence to show whether the composition of any one part of the body is an indication of the actual quality of the entire carcass. Maw (5) pointed out that large variations exist between individuals in their rate of gain and feed consumption, but the variation was reduced by a longer feeding period. Maw (7) has shown the relationship of size of stock in Barred Plymouth Rocks during growth to the rate of gain in 14-day confinement feeding, the 2-pound size making approximately 41% gain; 3-pound, 23%; 4-pound, 15%; 5-pound, 12%; 6-pound, 11%. The rate of gain is also correlated with feed consumption. The smaller sizes of stock, however, carried less flesh on the carcass than the mature-bodied stock. Jull and Maw (4) have also shown that the medium-sized stock in similar breeds make much greater gains than the mature stock.

It has been clearly shown by Heuser and Norris (2) that the rate of growth and protein requirement decreases as body maturity is attained, the higher protein levels only being necessary during the early stages of growth. Funk (1) has demonstrated with fattening stock that relatively simple rations in contrast to complex rations, although the protein levels were similar, produce similar quality in the carcasses. The work of Maw (6), with large-sized Barred Plymouth Rock stock, also shows that the protein level in a mixed cereal ration had relatively little effect on the rate of gain in 21-day feeding, as well as on the quality of the finished carcass as illustrated by the chemical analysis of the flesh, abdominal fat, and skin plus the external fat combined. The present problem deals with the effect of the protein level of the ration fed to birds of varying sizes during growth on the composition of one group of muscles known as the thigh.

METHODS

Stock

All stock, with the exception of a few in the largest size, were Barred Plymouth Rock cockerels of similar breeding, the others being Rhode Island Reds and Barred Plymouth Rock × Rhode Island Red crosses. The birds were reared on the range, being hopper-fed *ad libitum* mixed grain and developing mash up to the respective sizes when they were selected for the

[1] Contribution from the Faculty of Agriculture of McGill University, Macdonald College, P.Q., Canada, with assistance from the Dominion Department of Agriculture, Ottawa, Canada. Macdonald College Journal Series No. 81. Presented before the Annual Meeting, Poultry Science Association, Blacksburg, Va., Aug. 6, 1936.

[2] Assistant Professor of Poultry Husbandry and Head of the Department of Poultry Husbandry, Macdonald College.

[3] Lecturer, Department of Poultry Husbandry.

[4] Formerly, Research Assistant, Department of Chemistry.

[5] Formerly, Lecturer, Department of Poultry Husbandry.

fattening trials. Five different sizes of stock were selected to represent the different stages of growth from approximately two to six pounds in weight. The weight-range in each size was four hundred grams. The initial starved-weight classes for the different groups were: 901 to 1300, 1301 to 1700, 1701 to 2100, 2101 to 2500, and 2501 to 2900 grams. The numbers finished in each group varied somewhat, partly due to losses and partly due to lack of stock in the respective sizes when space was available for feeding. (See Table 1 for the numbers fed in each trial.)

Five hundred and thirty-six individuals were finished in the feeding trials and five individuals in each of the five size groups were dressed for analysis as check stock as coming from the range.

Treatment

Each group of individuals, according to size, was divided into five lots for feeding. Individual cooping was used throughout the experiment. Five different rations, varying in amount of animal protein only, were used. The cereal basal ration was made up of yellow cornmeal, 30 lbs., ground oats, 30 lbs., white wheat middlings, 26.5 lbs., and salt, 1 lb.; the animal protein supplement used was made up of beef meal, 7.5 lbs., and powdered buttermilk, 5 lbs.

PROPORTION OF BASAL MIXTURE TO SUPPLEMENT

Rations	1	2	3	4	5
Basal mixture—lbs.	100	97	94	91	88
Animal Protein Supplement—lbs.	—	3	6	9	12
	100	100	100	100	100

The basal ration was number one, and the other four had 3, 6, 9, and 12% animal protein supplement added. The total protein content of the five rations is given in the table of percentage composition. The range of total protein is from 14.18% in the basal ration to 22.69% in ration V.

PERCENTAGE COMPOSITION OF THE RATIONS

Ration No.	Moisture	Fat	Fibre	N × 6.25	Ash	N-free extract
I	10.56	5.24	2.78	14.18	2.53	64.71
II	10.33	4.78	2.60	16.42	3.19	62.68
III	10.17	5.34	2.48	18.09	3.51	60.41
IV	10.36	5.40	2.27	19.64	4.60	57.73
V	10.18	5.72	2.13	22.69	5.79	53.49

Method of Feeding

Individual feeding was carried on for a 14-day period, recording feed consumption and live weight gain at 7 and 14 days. Three full-feeds daily were given throughout the period. Any wet feed on hand at weighing period was weighed back and calculated on a dry-feed basis. The wet feed was mixed on the basis of one part dry feed to two parts water by weight.

Method of Preparing Samples for Chemical Analysis

The thigh muscles of both legs of each carcass for analysis were used. The dressed carcass was chilled for 24 hours before samples were taken. In removing the group of four thigh muscles—*sartorius*, *gluteus primus* and *semitendinosus*—the skin of the leg was removed with all subcutaneous fat attached to it. The interstitial fat laid down between the muscles was considered a logical part of the muscle, since these fat deposits are the natural result of maturation of body and fattening. Immediately upon removal, the entire muscles were thoroughly ground into a homogeneous mass from which three samples were taken for chemical analysis.

Method of Chemical Analysis of Samples

The method of analysis used was that described by Holcomb and Maw (3), where hydrochloric acid digestion for the fats is used.

The only modification was to allow the hydrochloric acid digestate to evaporate until the volume was somewhat less than that of the bottom bulb of the Mojonnier extraction tubes. Using one extraction tube for each sample, in place of two as formerly, reduced the necessary time spent on the analysis. Since the fat content of the samples was low (average 6.75% with a maximum of 14%), no losses occurred by foaming and no kerosene additions were necessary. In making the analyses for moisture, samples of from 8 to 10 grams were used rather than from 20 to 30 grams as described in the methods. Ash, protein, and nitrogen determinations were made as described.

ANALYSIS OF FEEDING DATA

The Effect of Initial Weight, Protein Level, and Feed Consumption on Fattening Gains

The experimental data obtained in these trials are given in Table 1. With regard to gain, it is to be noted that there is a considerable variation among the groups. It is evident that the different protein levels had no effect on the amount gained in the separate weight groups. When all weight groups are combined, the birds receiving rations containing smaller percentages of protein made slightly higher gains than those receiving the larger percentages of protein. However, the differences are so small that little importance can be attached to them. When classified on the basis of initial weight, it can be seen that the medium-sized birds, from 1300 to 2100 grams, made better gains than birds whose initial weights were below or above this range. Table 1 shows that in each ration group, with the exception of ration V, the gains were greater in the medium-sized groups. There was no difference in feed consumption between the ration groups. The figures for the gain-feed ratio show that the medium to small birds produced the greater gain per unit of feed consumed. The larger amounts of feed consumed by the larger birds did not produce a corresponding gain. It is probable that the greater maintenance requirements of these birds is largely responsible for the lower gain-feed ratio.

The relationships existing between the independent factors and gain were analysed by obtaining the simple, partial, and multiple correlation coefficients. The method used was that given by Wallace and Snedecor (8). Table 2 gives the results of this analysis.

TABLE 1.—MEAN VALUES OF INITIAL WEIGHT, GAIN, AND FEED CONSUMPTION

Ration		Weight groups (grams)					
		901–1300	1301–1700	1701–2100	2101–2500	2501–2900	Mean
I.	Number	14	26	22	23	23	108
	Initial weight	1035.71	1520.57	1869.09	2289.56	2695.65	1942.73
	Gain	189	262	280	194	238	236.80
	Feed consumption	1202.85	1462.61	1627.31	1861.78	1967.39	1655.00
	Gain per 100 grams feed	15.73	17.93	17.20	10.42	12.11	14.31
II.	Number	18	23	24	27	22	114
	Initial weight	1090.00	1525.00	1917.08	2352.04	2675.68	1956.79
	Gain	207	290	285	172	205	231.97
	Feed consumption	1278.88	1526.52	1760.50	1792.70	1918.95	1675.45
	Gain per 100 grams feed	16.20	19.01	16.23	9.60	10.73	13.84
III.	Number	23	24	21	23	24	115
	Initial weight	1092.82	1470.42	1914.52	2328.91	2677.70	1899.65
	Gain	169	342	302	160	165	227.09
	Feed consumption	1210.35	1466.54	1641.24	1782.61	1778.92	1575.61
	Gain per 100 grams feed	14.02	23.35	18.40	8.98	9.27	14.41
IV.	Number	20	23	23	16	22	104
	Initial weight	1092.00	1496.74	1885.65	2329.37	2672.50	1881.73
	Gain	203	369	186	77	150	205.67
	Feed consumption	1200.25	1460.30	1524.65	1671.81	1918.54	1554.00
	Gain per 100 grams feed	16.97	25.29	12.20	4.63	7.81	13.23
V.	Number	15	24	14	23	19	95
	Initial weight	1073.00	1448.12	1882.85	2278.69	2735.52	1911.53
	Gain	56	320	183	95	230	186.05
	Feed consumption	1023.20	1393.58	1378.07	1763.17	1976.95	1538.97
	Gain per 100 grams feed	5.53	23.00	13.29	5.40	11.64	12.09
Mean	Number	90	120	104	112	110	536
	Initial weight	1079.88	1492.33	1894.85	2316.16	2690.00	1919.11
	Gain	169.00	315.87	252.10	144.91	196.77	218.66
	Feed consumption	1189.45	1461.40	1604.60	1781.48	1908.46	1602.15
	Gain per 100 grams feed	14.21	21.61	15.71	8.13	10.31	13.65

TABLE 2.—CORRELATION COEFFICIENTS

——	Simple	First order partial	Second order partial
Initial weight—Gain	−0.1284		
Initial weight—Feed Consumption	.6355		
Initial weight—Protein consumption	.5585		
Initial weight—Gain (feed eliminated)		−0.5200	
Initial weight—Gain (protein eliminated)		− .3519	
Initial weight—Gain (feed and protein eliminated)			−0.2751
Feed consumption—Gain	.3818		
Feed consumption—Protein consumption	.8284		
Feed consumption—Gain (initial weight eliminated)		.6053	
Feed consumption—Gain (protein eliminated)		.2890	
Feed consumption—Gain (initial weight and protein eliminated)			.1820
Protein consumption—Gain	.2729		
Protein consumption—Gain (initial weight eliminated)		.2446	
Protein consumption—Gain (feed eliminated)		− .0838	
Protein consumption—Gain (initial weight and feed eliminated)			− .1437

Multiple R = 0.6151

The level of high significance for the simple correlations is 0.115 (table given by Wallace and Snedecor). All the coefficients obtained are significant. Initial weight shows a moderate negative correlation with gain. Removing the effect of feed consumption and protein consumption, which are in part duplications, increased this coefficient. High coefficients are obtained between the other factors and gain in both the simple and partial correlations.

The multiple R was found to be 0.6151. The level of high significance for this value is 0.150. It can be seen from this figure that there exist in these trials a considerable variation in gain, produced by experimental error or other unknown factors.

By means of the regression coefficients of the known factors on gain, it is possible to determine the relative effect of each on the portion of the total variation in gain produced by these factors.

TABLE 3.—RELATIVE EFFECT OF INDEPENDENT VARIABLES

Variable	Symbol	Standard regression	Percentage or weight
Initial weight	A	−0.6183	40
Feed consumption	B	.8370	55
Protein consumption	C	− .0753	5
		1.5306	100

ANALYSIS OF VARIATION

Source	D/F	Sum of squares	Mean square	Standard deviation
Due to regression	3	6,007,793.56	2,002,597.85	
Not accounted for	532	9,869,039.32	18,550.82	136.20
	535	15,876,832.88	29,676.32	172.26

It can be seen from Table 3 that the major part of the variation in gain is determined by initial weight and feed consumption. Protein consumption had relatively little effect on the gains in these fattening trials. It must be remembered, however, that these relative effects apply, not to the total variation in gain, but only to that portion due to these independent factors.

Chemical Analysis of Thigh Muscle

Results of Analyses

In a few cases the determinations of moisture, fat, protein, and nitrogen were doubtful, owing to deviating too widely from the mean deviation for the group in question. Such analyses were discarded. In all, the values of four for moisture, one for fat, and five for protein and nitrogen were discarded.

TABLE 4.—MEAN PERCENTAGES OF FAT

Ration	Weight (grams)					Total
	901–1300	1301–1700	1701–2100	2101–2500	2501–2900	
Check	3.13 ± 0.336	4.29 ± 1.038	4.47 ± 0.583	5.00 ± 0.623	4.36 ± 0.572	4.28 ± 0.274
I	7.14 ± 0.985	7.59 ± 0.769	6.97 ± 0.495	7.56 ± 0.995	9.57 ± 0.652	7.67 ± 0.395
II	7.29 ± 0.617	6.89 ± 0.636	5.64 ± 0.499	8.06 ± 0.630	8.99 ± 0.632	7.37 ± 0.362
III	7.31 ± 0.985	5.81 ± 0.560	6.19 ± 0.413	7.88 ± 0.360	6.84 ± 0.419	6.87 ± 0.297
IV	7.19 ± 0.614	5.98 ± 0.309	6.16 ± 1.140	7.35 ± 1.384	6.65 ± 0.744	6.52 ± 0.393
V	5.53 ± 0.355	6.94 ± 0.510	5.21 ± 1.009	8.63 ± 0.510	7.23 ± 0.395	6.86 ± 0.374
Total	6.92 ± 0.376	6.64 ± 0.319	6.10 ± 0.348	7.94 ± 0.355	7.81 ± 0.341	

TABLE 5.—MEAN PERCENTAGES OF PROTEIN

Ration	Weight (grams)					Total
	901–1300	1301–1700	1701–2100	2101–2500	2501–2900	
I	18.05 ± 0.626	18.67 ± 0.606	18.46 ± 0.184	19.26 ± 0.842	19.22 ± 0.155	18.69 ± 0.285
II	17.75 ± 0.254	19.18 ± 0.456	19.20 ± 0.410	18.48 ± 0.412	19.07 ± 0.598	18.74 ± 0.222
III	18.51 ± 0.460	19.61 ± 0.262	18.64 ± 0.196	19.03 ± 0.258	20.86 ± 0.187	19.29 ± 0.217
IV	18.57 ± 0.437	19.44 ± 0.260	19.77 ± 0.571	20.22 ± 0.646	20.36 ± 0.005	19.62 ± 0.223
V	18.82 ± 0.387	19.22 ± 0.588	19.76 ± 0.199	19.32 ± 0.143	20.96 ± 0.288	19.64 ± 0.244
Total	18.33 ± 0.215	19.22 ± 0.214	19.17 ± 0.120	19.18 ± 0.251	20.15 ± 0.235	

Moisture

The effect of the ration on the moisture content of the thigh muscle was not significant, although the difference between the fattened stock and the check stock was significant. The decrease in moisture content as size of bird increases was greatest with the largest size, although no regular decrease was shown with increase in size.

Ash

Irrespective of ration or live-weight, the ash content of the thigh muscle is approximately 1%.

Fat

No significant differences are to be noted in the fat content of the thigh muscle as affected by the different rations. There is, however, a wide difference in the fat content as between the check stock and the fattened stock.

Protein

Increases of protein in the thigh muscle vary only slightly. There is some indication that there may be a slight increase with increasing live-weight.

TABLE 6.—ILLUSTRATING THE BASIS USED FOR DISCARDING THE RESULTS OF THE ANALYSES OF CERTAIN INDIVIDUALS FOR A GIVEN FACTOR

Determination	Mean percentage	Total of deviations from mean	No.	Average of deviations from mean	Four times average	
					Value	Exceeded by
Moisture	73.06	247.91	142	1.74	6.96	None
Fat	6.78	244.11	142	1.72	6.88	No. 31053
Protein	19.15	139.23	143	0.97	3.88	No. 1429
Nitrogen	3.168	16.938	143	0.118	0.472	No.1002, No. 795
Percent N in P	16.55	92.89	141	0.66	2.64	No.2822, No.1429

Nitrogen

As would be expected, the nitrogen content of the thigh muscle follows parallel to the protein content of the ration. With both the increasing of the protein content of the ration and the increasing live-weight there is an increased nitrogen content of the muscle.

TABLE 7.—SUMMARY OF THE EFFECT OF PROTEIN LEVEL AND OF LIVE-WEIGHT

—	Increasing protein	Increasing live-weight
Moisture	No change	Decrease
Fat	Decrease	Increase
Protein	Increase	Increase
Ash	No change	No change
Nitrogen	Increase	Increase

SUMMARY

It would appear from this study that the protein and fat content of the thigh muscle are not significantly influenced by different protein levels in the fattening ration; nor does it appear that the sizes of stock used hav any effect upon the chemical composition of the thigh muscle.

REFERENCES

1. Funk, E. M. Simple vs. complex rations for fattening poultry. U.S. Egg and Poultry Magazine, 39 : 28-29. 1933.

2. Heuser, G. F. and L. C. Norris. The influence of the protein level on the rate of growth in chickens. Proceedings 4th World's Poultry Congress, 328-342. 1930.

3. Holcomb, R. and W. A. Maw. The analysis and composition of the flesh of the domestic fowl. Can. Jour. Res. 11 : 613-621. 1934.

4. Jull, M. A. and W. A. Maw. Experimental results in fattening chickens. Poultry Science, 2 : 101-111. 1923.

5. Maw, W. A. Meat production in poultry. U.S. Egg and Poultry Magazine, 39 : 18-47. 1933.

6. Maw, W. A. Protein levels in the fattening ration. Poultry Science, 13 : 302-303. 1934.

7. Maw, W. A. How quality in poultry meat is affected by the distribution of fat in the carcass. U.S. Egg and Poultry Magazine, 41 : 32-36 and 41 : 16-19. 1935.

8. Wallace, H., and G. W. Snedecor. Correlation and machine calculation. Collegiate Press, Ames, Iowa. 1931.

Résumé

La teneur en protéine de la ration d'engraissement et son effet sur la composition du muscle des cuisses, chez les volailles de consommation de différents âges. W. A. Maw, A. J. G. Maw, R. Holcomb, et L. H. Bemont.

Il paraît d'après cette étude que la teneur en protéine et en matière grasse du muscle de la cuisse n'est pas influencée d'une manière importante par les différents niveaux de protéine que contiennent les rations d'engraissement. Il ne semble pas non plus que la taille des sujets employés exerce le moindre effet sur la composition chimique du muscle de la cuisse.

ABSTRACTS

PAPERS PRESENTED BEFORE SOILS GROUP OF THE C.S.T.A. AT FREDERICTON, JULY 14-15, 1936.

A QUANTITATIVE STUDY OF SYMBIOTIC NITROGEN-FIXING BACTERIA IN SOILS IN RELATION TO CROP ROTATION, SEASON, AND FERTILIZER TREATMENT

A. G. LOCHHEAD[1] AND R. H. THEXTON[2]
Central Experimental Farm, Ottawa, Ont.

By means of a dilution technique, in which the appropriate legume host plants were treated with a series of measured quantities of soil and observed for the occurrence of root nodules when grown under aseptic conditions, numbers of three species of *Rhizobia* were determined. Tests were made at 4-week intervals throughout a 4-year crop rotation (clover, timothy, mangels, oats) with three soils which had received no fertilizer for 20 years, manure, and artificial fertilizer respectively.

Relatively small differences were noted in the numbers of the clover organism *(Rh. trifolii)* in three soils. The pea-vetch organism *(Rh. leguminosarum)* and the alfalfa-sweet clover organism *(Rh. meliloti)* persisted in much higher numbers in the fertilized areas than in the unfertilized soil (21 to 25 times and 6 to 10 times respectively). *Rh. trifolii*, the only species with host plant in the rotation, occurred in much greater numbers than the other species, not only with and immediately after clover, but in later years when little or no decline was noted. This suggests greater need for re-inoculation of alfalfa, vetches, etc., than for red clover.

Apart from the effect of clover on the clover organism no significant effect of cropping was noted, nor was seasonal influence important. Numbers were not affected by 3-months' freezing each year, an important consideration in the maintenance of successful legume cultivation in regions with severe winters.

Comparison between the relative productivity of the areas and the bacterial population, showed no agreement in the case of *Rh. trifolii*, *Azotobacter* (free living nitrogen-fixing bacteria), or the total numbers of bacteria. Numbers of *Rh. leguminosarum* and *Rh. meliloti* were more in agreement though only in the case of *Rh. meliloti* were relative numbers consistent with the soils in order of crop yield throughout the four years.

---

[1] Dominion Agricultural Bacteriologist.
[2] Bacteriologist.

STUDIES ON THE MICROBIOLOGY OF PODSOL SOILS IN QUEBEC

P. H. H. Gray and H. J. Atkinson
Macdonald College, Quebec

Limestone stimulated the activity of micro-organisms in Appalachian upland podsol soils; simple fertilizers and summer fallowing had no effect. Deep ploughing reduced activity. Treatments with calcium oxide, sodium carbonate, and sodium carbonate singly or in combination stimulated the production of carbon dioxide, bacterial numbers, and nitrification. The effects lasted through two seasons. Numbers of bacteria showed seasonal fluctuations of considerable extent that were similar in three widely separated soils; in one year numbers were lower in summer than in spring and autumn; in the next year, numbers were low in autumn. Microbiological activities were at different levels in the two years. Seasonal fluctuations were of a greater order of difference than the changes due to treatment.

STUDIES OF THE ELEMENT PHOSPHORUS IN PASTURE SOILS

C. L. Wrenshall

The importance of phosphate fertilization in the improvement of pastures is reviewed.

Chemical studies show: 1, the amounts of organic and inorganic water-soluble phosphorus; 2, that the fixation of superphosphate applied to the surface occurs in the top one-half inch of soil. The availability of the phosphate so fixed is estimated by the Quebec extraction method, and shown to decrease regularly with the removal of successive crops.

Pot-culture experiments show: 1, a depression of yield and phosphorus uptake due to the addition of limestone to the soil; 2, an increase of yield and phosphorus uptake due to the addition of elemental sulphur to the soil.

High yields of organic phosphorus compounds resembling nucleic acids have been obtained from soil. The importance of this material is discussed.

BOOK REVIEWS

GREENSLADE, R. M.—Horticultural aspects of woolly aphis control together with a survey of the literature. Tech. Comm. Imperial Bureau of Fruit Production, East Malling, Kent, England, 8, 1936, pp. 88, bibls. 555 (general) and 156 (biologic control), 2s. 6d.

The voluminous literature published during the last hundred years on woolly aphis or American blight, and the divergence of opinion there expressed have long demanded examination and critical analysis.

In November 1933 a memorandum and questionnaire on the incidence and control of the pest was circulated by the Imperial Bureau of Fruit Production to all the apple growing countries of the world and co-operation invited.

The literature and the replies to the questionnaire have been thoroughly sifted by the present author, who has for some years at East Malling been testing new seedlings for immunity, investigating control measures in the orchard and studying the causes of immunity or resistance, and is, therefore, in an exceptionally good position for examining the situation. This he does most clearly and concisely for practical horticulturists no less than for fellow investigators in Technical Communication 8.

First the insect and its habits, its spread in the orchard, its methods of feeding and its possible alternative hosts are dealt with. Next the bearing of climatic factors, temperature, humidity, wind and sunlight, on its incidence is considered. In many parts of the Empire the normal combination of these factors is propitious for a heavy attack, whereas in England an increase in temperature and sun and in Roumania an increased rainfall will induce it. Control measures are considered in detail:—(1) Artificial control including spraying, fumigation, tree injection, cultural practice, etc. (2) Natural control by *Aphelinus mali* and other parasites. The varying measure of success achieved in different countries is noted. (3) Control by use of resistant stocks and varieties. A particularly interesting account is given of existing resistant varieties, of the breeding work in progress in England at Merton and East Malling and of the few indications afforded as yet of the possible causes of resistance. Lastly (4) Control by legislation, *e.g.*, quarantine measures, etc.

The literature from nearly 300 sources is further dealt with in the two annotated bibliographies which follow. The first, general, contains 555 references, while the second contains 156 references to articles on the biologic control of the pest.

Finally the memorandum and questionnaire noted previously are reproduced in full together with a list of persons who replied. This list forms, incidentally, a useful index of workers interested in the subject.

Both to investigators and growers this publication should prove of great reference value.

KRIEGER, LOUIS C. C.—The Mushroom Handbook. Illustrated by photographs and drawings by the author. The Macmillan Company, New York, 1936; 8°. 538 pp. $3.50.

"Here is the most complete handbook of mushrooms ever published, by one of the outstanding authorities on the subject in the United States"—Thus the publisher!

There are 126 illustrations, mostly pen and ink drawings by the author, but including quite a few excellent photographs and 32 coloured plates, of which 19 are published for the first time, in this volume. Plates 1 and 18 are rather striking and introduce quite a bit of colour in the scheme. The others are really good, somewhat idealized, but ever so much better than many others we have seen. The index

covers 25 pages and is very complete, but it is one of the indexes that tax the patience of the impatient student. Under *Amanita muscaria* for example, are 20 page numbers, one after the other. What an author saves in time—a publisher in space—the printer in ink—every single reader has to pay for in time and patience. In these days of efficiency, dear authors, heed the plea of an interested, but busy reader. Thus if, under *A. muscaria*, we would find:— Ectotrophic mycorrhiza, of . . . . p. 35; gravity effect of, in . . . . p. 43; fairy rings, of . . . . p. 44, and so on, it would save us a lot of time, and all of us would appreciate the trouble of the author. The bibliography is extensive and up to date—very useful.

I must particularly compliment the author on his well chosen figures to clearly illustrate many features and terms one comes across in text books, which leave much to the reader's imagination. I have gone carefully through this interesting, handy, little book and find that it is highly to be recommended. Krieger is a recognized authority on fungi whose reputation has indeed gone beyond the United States. In Canada and even in Europe one hears most appreciative comments about his power of observation, his accuracy and above all his reliability in his treatment of a subject that requires such careful handling as the edibility of fungi—for too much cannot be said about the dangers attending the eating of mushrooms one does not know thoroughly.

Krieger certainly makes matters quite clear to the non-technical reader, and even the technical reader will derive much information of value to him on almost every page.

—H. T. Güssow.

NOTES

ECONOMIC ANNALIST

For a period of approximately three years the *Economic Annalist*, prepared and edited by the Economics Branch of the Dominion Department of Agriculture, was published as a section of *Scientific Agriculture* and reprinted as the *Economic Annalist*.

It was recently decided that the *Economic Annalist* should resume its status as an entirely separate publication and it is now appearing bi-monthly as a publication of the Economics Branch of the Dominion Department of Agriculture. Members of the C.S.T.A. and subscribers to *Scientific Agriculture* who are not on the mailing list to receive the *Economic Annalist* may receive it free of charge on application to the Economics Branch.

ERRATUM

Dans le résumé donné à la page 208 du numéro de décembre 1936, la dernière partie de la phrase "4. Peu de potasse assimilable et forte proportion de phosphore et de potasse dans les horizons inférieures du sol" doit se lire: ". . . . et forte proportion de phosphore par rapport à la potasse, spécialement dans les horizons inférieures du sol".